VOLUME XIV NUMBER 10 WHOLE NUMBER 108

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
OTTO KLOTZ
Director of the Dominion Observatory, Ottawa
SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Director of the Dominion Astrophysical Observatory Victoria, B.C.

PUBLISHED MONTHLY
(*Ten numbers per year*)

December, 1920

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON
28 ESSEX ST., STRAND, LONDON

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. XIV, No. 10 DECEMBER, 1920. WHOLE No. 108

Articles		PAGE
The Calcium LinesH and K in early Type Stars	*Rehnold K. Young*	389
The Spectroscopic Orbits and Dimensions of the Eclipsing Variables U Coronae TX Hercules and Y Cygni	*J. S. Plaskett*	409
The Festival of the Dead	*R. J. Haliburton*	425
Notes from the Dominion Observatory Victoria, B.C.	*J. S. Plaskett*	428
Notes from the Meteorological Service		430
Book Reviews	*C. A. Chant*	434
Notes and Queries	*C.A.C.*	435
Index to Volume XIV.		437

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

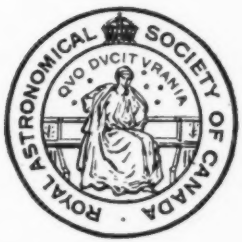
OTTO KLOTZ
Director of the Dominion Observatory, Ottawa

SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Director of the Dominion Astrophysical Observatory Victoria, B.C.

PUBLISHED MONTHLY
(Ten numbers per year)

Volume XIV, 1920.



PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON
28 ESSEX ST., STRAND, LONDON

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. XIV DECEMBER, 1920 No. 10

THE CALCIUM LINES H AND K IN EARLY TYPE STARS

BY REYNOLD K. YOUNG.

In 1904 Hartmann[1] discovered that the calcium lines H and K in the spectrum of δ Orionis did not share in the large oscillation shown by the other lines. While the hydrogen, helium and other elements gave a displacement, which, interpreted as the result of radial velocity, amounted to about two hundred kilometers per second, the calcium lines remained stationary within the error of measurement. Many other stars have been found which show the same effect. What was once thought to be an exceptional phenomenon is now quite usual. Miss Heger[2] has recently added the important discovery that several stars which show the stationary calcium lines also give constant velocities for the sodium lines D_1 and D_2.

At the present time there is a considerable amount of material bearing on the subject scattered through the periodicals, more in fact than some writers seem to realize. It is the object of the present paper to collect this and to add such unpublished data as the writer has at his disposal. Some of the suggestions which have been made from time to time as to

the nature and cause of the calcium absorption will be discussed in the light of present information and an attempt made to decide on the most favourable hypothesis. It is hoped also that the collection of material already at hand will show best where we can direct our energies in securing further observations.

Observational Material.

The Harvard Revised Photometry (Volume 50, H. C. *Annals.*) lists 937 stars as belonging to B-type. Of these only 303 are in the northern hemisphere. As will be seen presently the phenomenon is connected only with stars of early B-type. There are only 64 stars listed in the northers skies earlier than B3, and we have already at hand material for the majority of these.

Table I. contains a list of stars which have either been published as showing peculiar calcium lines or are known from other sources to belong to the class. It includes the twenty-four stars given in the *Publications of the Lick Observatory*, Volume 13, and many others discovered later. The list is not exhaustive, due to material doubtless at hand at other observatories but not yet published. In the *Astrophysical Journal*, Rufus[3] publishes a list of five Oe5 stars which he mentions as showing small range. These have not been included in the table. In 1909 Frost[4] found that he was able to list twenty-five stars showing sharp and narrow H and K lines, and for some of these we believe no information has been published. However, the table gives all those stars which have been studied with any detail and includes many stars which have not been considered by various writers in commenting on the cause of the peculiar behaviour of the calcium lines [5,6]. Orbits have been published for a bare majority of the stars, a few of them have been extensively observed without a period being discovered and a great many await future investigation.

TABLE I.

	Star	R.A. 1900	Dec. 1900	Type I	Type II	Vo Calcium	Vo	V_{sun}	P Days	K Primary	K Ca	e
		h m	° ′									
1	Boss 46	00 12.4	+50 53	A	B2	−23.5	−44.9	− 7.0	3.52	217.4	10.	.09
2	κ Cass.	27.3	+62 23	B	Bo	−16.8	− 3.0	− 8.0				
3	Boss 443	01 52.9	+75 01	A0	B5							
4	o Persei	03 38.0	+31 58	B1	B1	+12.4	+18.5	+ 6.5	4.42	111.9*	.00	.0
5	ξ Persei	52.5	+35 30	Oe5	Oe5	+15.4	+65±	+ 6.2	6.95	?	8	.03
6	9 Camel.	04 44.1	+66 10	B	Bo	− 2.2	+ 6.3	− 3.0				
7	π4 Orionis	45.9	+ 5 26	B3	B3	+16.1	+23.3	+15.4	9.59	25.9	21±	.03
8	η Orionis	05 19.4	− 2 29	Bl	Bl	?	+35.5	+16.9	7.99	144.8	?	.02
9	ψ Orionis	21.6	+ 3 00	B2	B2	+13±	+12.0	+17.4	2.52	144.1*	80+	.06
10	χ Aurigae	26.2	+32 07	B1	B1	+ 1.5	− 0.1	+ 9.1	655.2	20.5	10.5	.17
11	δ Orionis	26.9	− 0 22	B	Bo	+18.7	+15.2	+17.1	5.73	100.	00	.08
12	VV Orionis	29.0	− 1 13	B3	B3	+14.4	+21.0	+17.1	1.49	132.4	5±	.0
13	φ1 Orionis	29.3	+ 9 25	B	Bo							
14	θ2 Orionis	30.5	− 5 29	B1	B1							
15	ι Orionis	30.5	− 5 29	Oe5	Oe5	+30.1	+21.3	+15.9	29.1	109.9	0±	.75
16	ε Orionis	31.1	− 1 16	B	Bo							
17	ρ Gemin.	06 23.0	+20 17	B5	B5	+16.9	+38.5	+12.7	3500.	30.	?	.20
18	42 Camel.	40.5	+67 41	B3	B3							
19	29 Can. Maj.	07 14.0	−24 23	Oe	Oe	?	−12.1		4.39	218.4	?	.16
20	30 Ur. Maj.	10 16.9	+66 04	A	A				11.58	36.1	36.1	.35
21	ρ Leonis	27.5	+ 9 49	Bp	Bp	+10.0	+43.2	+ 4.5	12?			
22	θ Virginis	13 04.8	− 5 00	A	A							
23	β Scorpii	15 59.6	−19.32	B1	B1	−12.4	− 8.5	−10.9	6.83	126*	10±	.27
24	σ Scorpii	16 15.1	−25 21	B1	B1				12.92	184*	184±	.02
25	β Lyrae	18 46.4	+33 15	B2p	B2p							
26	Boss 4870	19 03.1	+41 16	A	B2							
27	σ Aquilae	34.3	+ 5 10	B8	B5	−12.6	− 5.0	−16.7	1.95	163.5*	0±	.0
28	Boss 5070	19 47.2	+40 20	A	B3							
29	Boss 5150	20 00.7	+31 56	G	B2							
30	Boss 5236	20.0	+37 10	A	B							
31	Y Cygni	48.1	+34 17	A	B2	−11.0	−49.1	−18.3	3.00	224*	0±	.0
32	H.R. 8427	22 02.0	+47 45	A	B2	+ 1.5	−17.8	−14.0	2.17	127.7	0	.0
33	12 Lacer.	37.0	+39 43	B2	B2	− 8.0	8.5	−16.1	0.19	var.	var.	.0
						−17.7	19.1					
34	Boss 5918	52.7	+48 09	B3	B3							
35	H.R. 8800	23 02.7	+45 33	A	B3	− 8.3	−16.2	−10.6	3.34	88±	0.0	.23
36	H.R. 8803	03.0	+59 13	B2	B2		− 7.5	−11.1	7.25	47.		.39
37	Boss 6142	23 50.5	+56 53	Bp	Bp	−24.0	−26.7	− 8.8	13.43	115.5*	0+	.10

The first four columns of the table need no explanation. Column five gives the type of spectrum as listed in *H.R.* 50. Column six gives a corrected type, based on either later determinations such as the revised Draper catalogue, the Mount Wilson Publications, or the spectrum has been examined here. Column seven gives the velocity of the center of gravity of the system as determined from the calcium lines H and K if an orbit was based on these or the mean velocity found for them if they were treated as constant. In all cases this has been reduced to the wave length 3933.825 for the K line. The velocity of the system as determined for the other lines in the spectrum is found in column eight, and the

ninth column gives the velocity of the solar motion toward the star. The remaining four columns give approximate data relative to the orbits and are readily understood from the headings. In the column giving the semi-amplitude K, those which are marked with an * show a secondary spectrum.

Spectral Type.

Considering the relative numbers of B-type stars in column five to stars of later types, one would suspect that the stationary calcium lines had a tendency to occur in the early types. This fact was first mentioned, I believe, by Jordan[7] and commented on by the writer also[8]. The types in column five, especially toward the end of the table, would seem to question this relationship, but the next column where the types have been corrected leaves no doubt on the question. It seems remarkable that out of 37 listed examples so many should be in error in type of spectrum, and it makes one wonder whether there are not more B-type spectra among the faint stars than at present supposed, for it is faint spectra that are most liable to be misjudged. In examining column six we note that there are two A-type spectra, but neither of these stars should be listed in the table.

The first is 30 Ursæ Majoris (R. A. 10h 16.9m). It was announced as a binary in the publications of the Allegheny Observatory[9]. Considerable difficulty was encountered in getting a satisfactory orbit, and the one given in the reference above was determined for the hydrogen and calcium lines separately. As these showed a small difference in range, the star has been usually classed as belonging to the list of stars with peculiar calcium lines. The orbit has been reinvestigated by Schlesinger, and he finds that the two hydrogen lines differ more from one another than either do from the K line. The conclusion is that there is no abnormal behaviour in the calcium lines.

In the second case, θ Virginis (R. A. 13h 04.8m) the data are very meagre. It was published as a binary by Mitchell in

the *Astrophysical Journal*, Vol. 30. Eleven plates were taken and these show a range for the hydrogen and helium lines from —6 to +16. The calcium lines were measured only on three plates. On the first K gave +14.6, while the whole plate gave—1.4. On the second plate K gave +5.2 and the whole plate +4.3, while corresponding values for the third plate were —6.7 and +7.3. The range in the calcium is about the same as the other lines. Bearing in mind the uncertainties of single line velocities the star need not weigh very heavily as evidence until investigated further.

Leaving 30 Ursæ Majoris, and θ Virginis aside practically all the stars are of type B2 or earlier, but too much stress should not be placed on the exact subtype number. Anyone who has examined B-type spectra realizes the difficulties in a natural classification. In the first place, in some stars the lines are so faint and diffuse as to be almost invisible, while in others the lines are beautifully sharp and narrow. The Draper classification nominally at least is based on the relative intensities of the lines. When the lines are sharp and narrow they are easily seen, and the criterion is quite definite, but among the very poor-lined stars the exact classification is more difficult. The line 4267 assigned to carbon is quoted as appearing in B2 spectra, but absent in B3. If we make this a deciding point several of the stars listed as B3 would drop back to B2. In any case it seems that the phenomenon is connected with stars of early type rarely as late as B3 on the Harvard scale. This fact makes it almost certain that the calcium vapour causing the absorption is connected with the star. That is, there is a stage in the effective age of a star at which it shows the stationary calcium lines, and this stage occupies a comparatively short interval of the time-scale in a star's life.

All the stars listed in Table I. are north of —20° declination. If we list all the stars of type B2 or earlier given in *H. R.* 50 and above the same declination, we find we have information on only fifty. Fourteen seem to give constant velocity. In these cases it is impossible to investigate the behaviour of the calcium lines. In all those for which an orbit has been

published and the H and K lines investigated, the latter have been found either to be stationary or to yield a range less than the other lines.

At the present time it would be safe to say that if a star is a spectroscopic binary and shows calcium lines giving a smaller range than the other lines, it will be B3-type or earlier, and conversely if a star of B2-type or earlier is found to be a binary, the calcium lines will give a smaller range than the other lines. The converse statement needs to be qualified slightly. There are several stars listed as B2 which have very wide and diffuse lines, and in which the K line is also very poor, and hence it has not been investigated separately. θ Virginis is an example of this class. The problem of the wide and diffuse character of the spectral lines in some of these stars is a much wider one than that of the stationary calcium lines. It comes up not only in B-type spectra, but also in stars of A- to F-types, and even in still later types. It probably is connected with the motions and conditions of the gases in their reversing layer while the stationary calcium lines have their origin outside this region, and if this is the case, the fact that we observe many stars at present listed as B2, which have no sharp K line, would show that there are stars of early B-type without the calcium envelope.

Theories to Account for the Phenomenon.

Hartmann in his original paper on δ Orionis put forward three hypotheses to explain his results. The first hypothesis was that the upper atmosphere of the earth contains calcium sufficient to produce the narrow line. He did not suggest this seriously, and at once ruled it out because in that case the line should be present in all stars. A second suggestion that the narrow lines had their origin in a very massive secondary surrounded by a calcium atmosphere can hardly be said to be much easier to accept. The difficulties that beset this interpretation occurred to Hartmann, and among others he mentions the great mass necessary to assign to the secondary and

its peculiar spectrum consisting of the two lines H and K. He, therefore, proposed the theory that the absorbing gas is "not in immediate connection with the star," and he follows this with the further addition that the cloud lies between the star and the observer.

Shortly after the appearance of Hartmann's paper, Julius[11] suggested that δ Orionis was not a spectroscopic binary, and that it was surrounded by a large tenuous cloud of calcium vapour. The rarity of the atmosphere accounted for the narrow absorption lines while the apparent irregularities in the other lines were due to what he called "anomalous refraction." The great number of subsequent discoveries of stars with fairly sharp lines which show large periodic displacements and some with both spectra visible and eclipsing variables leave no doubt whatever the stars are genuine binaries and that Julius' theory, however efficacious it may be in explaining irregularities in the character of the lines, cannot overcome the difficulty of explaining the oscillating lines. Almost everyone who has worked in this field is convinced to-day that the stars are binaries and that the narrow H and K lines have their origin in a cloud at low pressure.

There are three distinct ways in which we may regard the calcium cloud as causing the presence of the H and K lines in these stars. First, Hartmann's suggestion that the cloud lies between the observer and the star. Second, the nebulosity surrounds the star, but is not an integral part of it, being in the nature of the diffuse nebulosities that we can photograph in the background of the sky in several regions where the B-type stars are numerous. Third, the calcium cloud is part of the star's atmosphere, but possibly much more extended than the reversing layer proper. We will consider the difficulties connected with these theories in turn.

First Hypothesis.—The great objection to Hartmann's suggestion is, that so far all the stars that show the phenomenon are of one spectral class. In this regard it might be urged possibly that the B-type stars being so very distant are beyond certain nebulosities in the Milky Way, while stars of later

type are nearer and accordingly escape showing the calcium absorption. This method of avoiding the difficulty can hardly be resorted to in considering the stars of early and late B-type.

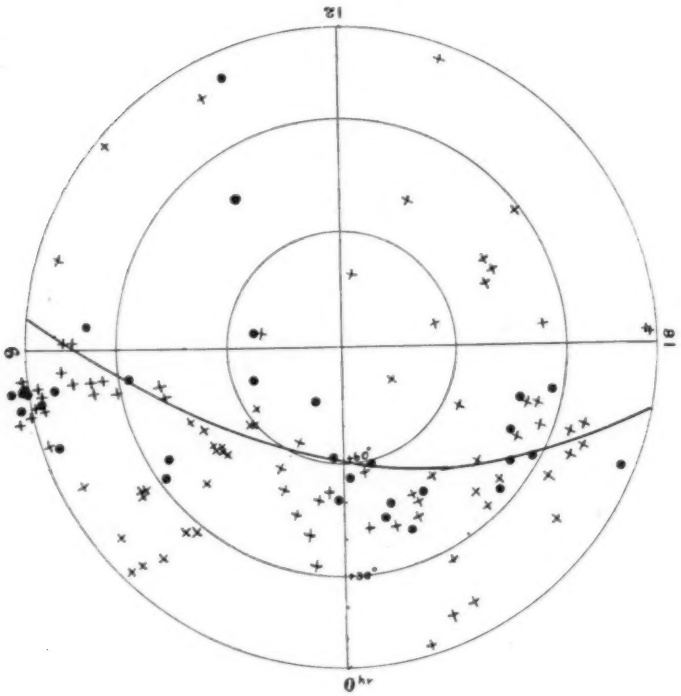


FIG. 1.—North Celestial Hemisphere. The round black dots show the position of the stars with stationary calcium lines; the B3 and B9 stars are shown by small crosses.

In figure 1 are plotted all the stars showing the stationary calcium lines. They are plotted as round black dots. Only the northern hemisphere is shown, as data are at hand for this hemisphere only. The B3 and B9 stars are also plotted as small crosses, and these are found in the same general regions. If Hartmann's theory were correct it would seem that we

should find more cases among the late B-types than among the early for they outnumber the latter very much. The fact that we do not argues very strongly against the theory, and it also argues against the second hypothesis for both the early and late B-types are found scattered through the same regions and only the early types show the phenomenon of stationary calcium lines.

The agreement between column seven and column nine in the table of stars has been urged as showing the calcium vapor to be of a nebulous nature and at rest in space. Why should we regard it at rest? As a matter of fact the difference for several stars is large. For Boss 46 it is over 16 kilometres, for ι Orionis it is over 14 kilometres, and in H. R. 8427 it is over 15 kilometres. Agreement or disagreement lends little weight to the argument either way, and in view of other objections Hartmann's suggestion cannot be accepted.

Second Hypothesis.—We believe also that this hypothesis, that it is the diffuse nebulosities which are responsible for the calcium absorption, is not correct. We mentioned before that the similar distribution of early and late B-type stars was an objection to it. The Pleiades also affords evidence to the contrary. These form a group of stars well known to be surrounded by a nebulous cloud, and the stars do not show a narrow and sharp K line. All the lines are wide and diffuse. The stars are mostly of B5-type. An important observation bearing on this subject has recently been secured by H. H. Plaskett. Spectrograms of two early type stars only a few seconds of arc apart show quite different calcium lines. The earlier type shows a fine sharp line, and the other a somewhat later B-type shows quite an ordinary K line. Now that the Draper Catalogue is so near completion, it should be possible to find more pairs of stars of this nature.

Third Hypothesis.—The third hypothesis, that the calcium cloud is a part of the star's atmosphere, seems most satisfactory to the writer, and the following facts may be adduced in support. There is concrete evidence in the case of 12 Lacertæ that the calcium is closely associated with the star. 12

Lacertæ was discovered by the writer to have a period of about four and one-half hours, and the calcium lines give about half as large a range as the other lines. The velocity of the system as determined from the H and K lines agreed with the velocity of the system, but series of plates taken in consecutive years showed both to be varying. The value so far are

	1913	1914	1915	1918
Hydrogen and Helium.....	—8.5	—11.2	—15.6	—19.1
Calcium	—8.0	— 9.1	—11.2	—17.7

We must conclude that the calcium vapour causing the absorption is moving with the star and also that it is so limited in extent that it surrounds the origin of the short period variation whether we regard it as a binary or a pulsating nucleus, but does not extend to the distant companion which presumably is the cause of the variation of the centre of mass. H. H. Plaskett's observation showed that the cloud must have an apparent diameter of less than a few seconds, but it would further appear as if the angle at the observer is extremely small. On two occasions the writer exposed a plate in the spectograph for about ten times the normal exposure time, keeping the star image as stationary as possible on the slit and behind a small strip of paper which cut off about two seconds of arc. The idea was that if an extended atmosphere existed it might record as a bright line outside the region of continuous spectrum. The result was entirely negative although possibly this was to be expected in view of the probably very faint emission.

There is a fact which at first sight seems contradictory to this third hypothesis. The velocity as given by the calcium lines is usually not in agreement with the velocity of the system as derived from the other lines, and up till recently the investigated orbits gave values which agreed quite closely with the component of the sun's motion toward the star. The data are set forth in columns 7, 8 and 9. Column 7 gives the velocity derived from the calcium lines. This depends so far as the writer was able to reduce the observations on the wave length 3933.825 for K. Column 8 gives the velocity from the lines of helium, hydrogen, carbon or whatever other elements

were present and the ninth column gives the velocity of the sun toward the star. It is the discordances between columns 7 and 8 which have been taken to indicate a separate origin for the calcium. Obviously the velocity obtained depends on the wave length adopted and when velocities from two lines or sets of lines differ we can make them agree by altering the wave length of either the one or the other. In the spectrum of P Cygni[12], Merrill found that the silicon lines were displaced one-fourth of an angstrom unit to the red when the other lines in the spectrum were taken as standard, yet no one suggests that the silicon is due to an intervening cloud. Albrecht found that the wave length[13] varied with the type, and apart from this systematic tendency there are undoubtedly individual discordances which in some cases amount to twenty kilometres. The question of the wave-lengths of the lines in stellar spectra is very complicated, and one about which we know very little in comparison to what is yet to be learned. It seems to the writer that, judging from the irregular manner in which wave-lengths of stellar lines shift from star to star, we are quite justified in assigning the differences between columns 7 and 8 to the selection of the wave-lengths upon which the velocities rest.

All the difference may not be due to variations in the wave-lengths of the calcium lines. In fact, it would seem that most of it should be assigned to variations in the other lines of the spectra. The reason for this is two-fold. Firstly, the calcium lines are sharp and narrow and presumably have their origin in gases at a low pressure, and so are less likely to be affected by disturbing influences. Secondly, the velocities from the calcium lines are more in accord with what we expect velocities of B-type stars to be. Take, for example, ξ Persei. If we take the helium lines we get an apparent velocity 65 km. or nearly 60 km. for the space velocity while the calcium lines give quite a normal result. Compare also ρ Leonis and Boss 46. In general also those stars which show the greatest difference between the two velocities are the ones with the broadest and most diffuse hydrogen and helium. (*cf* Y Cygni).

It is possible that the conditions which broaden the lines may also shift the centre.

A consideration of the novæ would seem to throw some light on these two hypotheses. Most astronomers, I believe, incline toward the collision theory for the origin of new stars. A comparatively faint star in its journey through space runs into a nebula, and the friction heats the star so that its light increases several magnitudes. When we consider that the nebulæ have actually been photographed surrounding these stars, and also that the lines of both sodium and calcium are sharp and narrow the connection between the novæ and stars showing stationary calcium lines looks pretty certain. There are, however, fatal objections to making the case of the stationary calcium lines similar to the novæ. Firstly, the early B-type stars have a stable spectrum which in other respects is not like the novæ spectrum, and, secondly, their light is constant. They are, therefore, not drifting through the nebula. It is much preferable to suppose that in the rapid gamut of types through which the novæ spectrum runs, *whatever be the cause*, it inevitably passes through the sharp H and K stage in the same way as possibly all stars will do or have done if they come to the B-type stage at all.

Accepting the hypothesis that the calcium vapour is a part of the true atmosphere of the star, we must find some way of explaining the stationary character of the lines. In 1915[14], the writer tried to show in a general way how this might come about from a large envelope enclosing the two nuclei, the whole rotating with the period of revolution of the two stars. This explanation breaks down when examined quantitatively, and it seems necessary to suppose that the outer layers of the calcium are not rotating as fast as the period of revolution.

In determining the orbit of σ Aquilæ[15] Jordan found that in addition to the stationary K on some plates there was another line near K whose position when measured was seen to coincide very nearly with one of the components. Later, finding it on several plates, he was led to re-examine plates of

other binaries, and he found strong evidence of the same thing in VV Orionis, β Scorpii, and especial in o Persei. The lines were very faint and Jordan does not think the evidence absolutely conclusive. *H. R.* 8803, whose orbit is now being investigated at this observatory by S. L. Boothroyd, shows evidence of the same thing. This is a very important result, and one worth settling with finality one way or the other. Plates should be taken at times when the components would be separated using fine-grained plates and narrow slit so that if possible the presence of the faint lines could be made certain.

Working Hypothesis.—In view of all the facts in the preceding paragraphs, the following working hypothesis is proposed for the origin of the calcium lines. All the early B-type stars are supposed to be surrounded by an envelope which is not a part of the reversing layer in which are found hydrogen, helium and other elements. Nevertheless, the envelope is not the extended nebulosity observed in the regions where these stars, abound, but it subtends at the observer a small and at present unknown angle. It occurs at a definite time as a stage in the life history of the star and gives rise to the sharp H and K lines and the D_1 and D_2 lines which will be stationary if the star is a binary. It is not clear whether the envelope is due to condensation of the extended nebulosities or comes from the star. One would favor the view that at first the cloud was the extended nebulosity, and that in this condition it does not absorb sufficiently to give rise to the K line. The calcium line in the reversing layer proper is also supposed to be very faint so that at this stage we would have those stars which give practically no K line at all. A later stage, as the surrounding cloud grows more condensed would be the sharp H and K stage, the calcium line in the reversing layer being very faint still, but growing stronger. This component is supposed to oscillate with the period of the binary, and at first it manifests itself as giving to the measures of the blended K line, a small range which increases as the component in the reversing layer grows stronger. The stage is approximately B0 to B2. A still later stage makes the line in the reversing layer

predominant, and the calcium lines then take on all the characteristics of the other spectral lines. This stage is reached as a rule by the time the star is B3-type. It is quite probable, however, in view of the present bright lines visible in late B-type stars and other anomalies that when the true line of evolution for these stars is known, the subtype numbers may be shifted around considerably, and we think that those stars which show the stationary calcium lines may form a class.

Observations Required.—In attempting to form a programme for attacking the problem of the stationary H and K lines several points and needs must be borne in mind. The addition of new orbits, in which the calcium lines give constant velocities, can add but little to the solution. Nevertheless, it is necessary to determine as many as possible in the hope that some feature but dimly shown in the majority will be prominent enough in some future star to be noticed. We refer to such characteristics as that discovered in σ Aquarii. Again, some stars about which there seems to be nothing abnormal need not receive particular attention, but those which already show peculiar and unexplained detail should be examined exhaustively. The table of stars will afford several stars of this nature. Many of the early results on B-type spectra were obtained with three-prism dispersion, and did not record the results of the K line. There is quite a wide and useful field for the small telescope and instrument in re-examining the bright B-type spectra with special reference to the K line. It will be of interest also to examine stars of Oe- and Od-type and earlier to find out the limit of the class in this direction. Already we have indications that the Oe5 stars as a class have the stationary calcium lines. The relation of mass to the phenomenon may also prove of interest. In A. N. 5046, Ludendorff tabulates the masses of these stars, and they are very great. Whether this is a true mass relation or whether it is because they belong to the B-type is not quite clear. We do find some stars of large mass which do not have sharp H and K, and so as far as the evidence goes at present it favours a direct relation between the sharp H and K and

the type, and so indirectly a relationship between mass and the sharp H and K, for only the massive stars reach the B-type stage.

NOTES TO TABLE I.

1. The orbit for this star is published in *Ap. J.*, Vol. 47, p. 329. The *Harvard Photometry* give the type as A, the Mount Wilson photographs as B3p. The new Revised Draper Catalogue calls it Bo. The hydrogen and helium lines give a range of 450 km. The calcium shows a range of 20 km. All the lines are faint and diffuse save the H and M, which are sharp and narrow.

2. κ Cassiopae was announced as binary by Campbell, L. O. B. 199. No orbit has yet been published. The results in the table are taken from the Dominion Observatory Publications, Vol. 4, p. 309. The spectrum shows the two silicon lines 4552 and 4557 in addition to the usual lines. All the lines are fairly sharp.

3. Three plates taken at this observatory by Harper are all the data available for this star, and the type listed B5 is judged from an examination of them. All the lines, including K, are rather wide. Harper's measures give a range of about 85 km for the hydrogen and helium, while the calcium K seems to give a very much smaller range.

4. This star was discovered to be a binary at the Yerkes Observatory and announced in the *Ap. J.*, Vol. 15, p. 214. A preliminary curve was determined by Vogel, *Ap. J.*, Vol. 17, p, 212. The present results are taken from the *Publications of the Allegheny Observatory*, Vol. 2,, p. 63, by Jordan. Both spectra are visible. The lines are of rather poor quality, but better than the rule in stars of this type which show a large range. The calcium lines are sharp and narrow. Jordan's results give the velocities of the calcium lines as stationary. A re-examination of the plates later in connection with the orbit of σ Aquilæ, showed a second K line which oscillated with the hydrogen and helium lines.

5. The hydrogen and helium lines in this star are extremely wide and diffuse, and no orbit has been determined from them. In the *Jour. R. A. S. C.*, Cannon publishes an orbit from the H and K lines which are sharp and narrow. The range is only 16 km. On some of his sheets, which were placed at the writer's disposal while at Ottawa, measures were shown of the other lines. They seem to show a very wide range and the mean seems to be very much higher than +15 km., probably +65 km.

6. The only orbit published for this star rests on the calcium lines, *Ap. J.*, Vol. 37, p. 1. It seems to the writer that until further investigated it would be unwise to use the elements in statistical investigation. The range of the hydrogen and helium lines, which, though quite broad,

are measurable, is small. The calcium lines are sharp and strong, and there can be no doubt of the reality of the variation indicated. The shape of the velocity curve is unusual, and the observations do not fit the computed curve at all well.

7 π^4 Orionis was anncunced as a binary by the Lick and Yerkes Observatories (*L. O. B.* No. 31, 1902, and *Ap. J.*, Vol. 17, p. 153.) The spectroscopic orbit was published by Baker in *Publications of Allegheny Observatory*, Vol. 1, p. 107. All the lines are of good quality, and it was only on re-examination of the data that it was discovered that the calcium lines gave a range about ten kilometres less than the other lines. The hydrogen and helium lines give a range of 52 km.

8. In the orbit of the star published by Adams in *Ap. J.*, Vol. 17, p. 71, no mention is made of the calcium lines, and presumably his spectra did not extend to that region. The lines are of good quality and show a range of nearly 300 km. Campbell, in his second catalogue, quotes a private letter from Slipher announcing H and K sharp and yielding constant velocity.

9. The lines in this star are rather wide and diffuse, but seem to be somewhat better than the average where there is such a large range in the radical velocity curve. In the orbit published by Plaskett no mention is made of the H and K lines, and apparently they were not measured. Harper, from 16 measures (*D. O. P.*, Vol. 14., 343) of the calcium lines finds they indicate a range of 80 to 90 km. The hydrogen and helium lines give a range of 300. Campbell, in the second catalogue of binaries, quotes a private letter from Baker stating that two spectra are visible and m_1/m 0.76.

10. An orbit for this binary was published by the writer in the *Jour. R. A. S. C.*, Vol. 10, p. 370. It is remarkable in the length of the period, 655 days. The lines are all sharp and narrow and the calcium lines give a range of 20 km which is about one-half the range for the other lines. Rufus in *Jour. R. A. S. C.*, Vol. 14, p. 139, finds some evidence that the hydrogen gives a smaller range than the other lines due to helium, silicon, etc. At the time of publishing this orbit I took the means of all the elements separately, and concluded from the same data that calcium was the only one that showed the effect. There is a peculiarity in the appearance of this star which was not mentioned in the published orbit. To the writer it has always appeared distinctly yellow or whitish in colour. It would be of interest to determine its colour index.

11. δ Orionis was the first star discovered in which the calcium lines gave a velocity different from the other lines. Recently Miss Heger has discovered that the sodium lines are also sharp and narrow, and give constant velocities. The lines are of fairly good quality and the secondary does not show. Two orbits have been published. The first by Hart-

mann in *Ap. J.*, Vol. 19, p. 268, and second by Jordan in the *Publications of the Allegheny Observatory*, Vol. 3, p. 125.

12. This star is an eclipsing variable. Daniel, in his published orbit (*Publications of Allegheny Observatory*, Vol. 3, p. 179) finds that there is no trace of the secondary on Seed 23 plates taken for the special purpose of finding it. The lines are rather broad and diffuse but fair. There is evidence of a long-period oscillation of about 30 km. amplitude and 120-day period. The calcium lines are not quite fixed, but seem to have an oscillation of about 10 km. amplitude. Jordan, in connection with an orbit for σ Aquilæ, finds evidence for this star of the presence of a second K line which shifts with the hydrogen and helium.

13. Very little has been published about this star. In *Ap. J.*, Vol. 30, p. 63, Frost and Lee give the results of the measures of 6 plates. The hydrogen and helium give a range of 12 km with a mean velocity of +40. Calcium shows a range of 34 km. with a mean of +20. All the lines are very sharp and narrow.

14. Announced as a binary by Frost and Adams in *Ap. J.*, Vol. 19, p. 153. The hydrogen and helium lines are broad and diffuse. They seem to give a range of about 140 km. No mention is made of the H and K lines. It is included in the Lick Observatory list of stars showing peculiar behaviour of calcium lines, Vol. 13.

15. An orbit of this spectroscopic binary is published by Plaskett and Harper in *Ap. J.*, Vol. 27, p. 272. The lines are rather wide and diffuse, and, though not mentioned, the calcium lines are presumably not very sharp and narrow, or they would have attracted attention. Slipher, in a letter to Campbell for the *Second Catalogue*, mentions H and K as giving constant velocities, and Harper from the result of 30 plates (*D. O. P.*, Vol. 4, 345, finds V_0 for calcium +30.1 There is some evidence of the presence of the secondary spectrum.

16. The results for this star are published by Frost in the *Ap. J.*, Vo. 29, p. 235. Hydrogen and helium are broad and diffuse, while H and K are sharp and narrow. Fourteen one-prism plates were secured. The variation indicated is small, and the evidence so far as it goes seems to show that the range of the calcium is as large as that of the other lines.

17. ν Geminorum was announced as a binary by Lee in *Ap. J.*, Vol. 32, p. 301. The measures indicate that the calcium lines give velocities differing from the hydrogen and helium lines. A large amount of work has been done on this star at Ottawa by Harper. *Jour. R. A. S. C.*, Vol. 13, p. 179. He finds the calcium lines are rather poor, and that the hydrogen and helium lines have a sharp core which gives a period of oscillation of 9.6 years not shown by the calcium lines. There is a short period oscillation as well. Until this short period oscillation is determined and the relation of the calcium lines shown to it we can hardly

say whether the star should be included in the class of binaries showing peculiar behaviour of the calcium lines.

18. Scarcely enough is known about the spectrum of this star to justify its being included in the list. It is announced as a binary by Lee in *Ap. J.*, Vol. 32, p. 302. The hydrogen and helium lines seem to be complex, and on the two plates on which H and K were measurable they gave velocities +17 and +17 as opposed to a mean velocity for the other lines from 5 plates of —4.

19. An orbit for 29 Canis Majoris is published by Harper in the *Dominion Observatory Publications*, Vol. 4, p. 115. The range is over 450 km, and the lines fair. No mention is made of a secondary spectrum and the lines are of fair quality. On only 4 plates was K measurable, but he remarks that it does not share in the large range of the other lines.

20. 30 Ursæ Majoris should not be included in this table, and it is so, only because included in former lists. Later investigation has shown that there is nothing peculiar in the behaviour of the calcium lines. (cf *All. Obs. Pub.*, Vol. 1, p. 121 and Vol. 2, p. 29.)

21. The results for this star are published in *Dominion Observatory Publications*, Vol. 1, p. 351. From 65 plates Harper was unable to find a period. All the lines are fairly sharp and narrow, and the two lines of silicon 4552 and 4567 are prominent. From a consideration of the residuals Schlesinger concludes that the period is in the neighbourhood of 12 days. (*cf. Ap. J.*, Vol. 31, p. 166.)

22. Very little is known about the calcium lines in the spectrum of this star. Its spectrum consists of many sharp and well-defined metallic lines, typical of A2-type.

23. Two orbits are published for β Scorpii, the first by Duncan in *Lowell Observatory Bulletin* No. 54, the other by Jordan in *Publications of Allegheny Observatory*, Vol. II., p. 137. There is quite a large difference in the two orbits for the velocity of the system and also a difference in the mean velocity for the calcium lines. There seems to be a small amplitude for the calcium lines. The lines are rather broad and diffuse and the secondary component is present. In connection with an investigation of Aquilæ Jordan finds that there is an oscillating K line as well as the stationary one.

24. The orbit for σ Scoprii has been published by Selga and also Henroteau, in the *Lick Observatory Bulletins*. Two periods are present, a six-hour one and a 34-day one. In the publication referred to no mention is made of the K line, but in a later *Publication Dominion Observatory*, Vol. 5, No. 1, Henroteau mentions the K line as being stationary. It would be interesting to investigate its behaviour with reference to the double period.

25. *Publications of the Allegheny Observatory*, Vol. II., p. 98, contains a long discussion of the results of the investigations on this star whose spectrum contains several sets of lines. The calcium line K was measured in the B8 spectrum and in the B5. The B8 lines oscillate with a range of about 200 km, and no mention is made of the calcium having a range different from the other lines. The B5 lines give zero range of velocity and the calcium line in this group agrees with the velocity of the system.

26. This star was announced as a binary by the writer in the *Jour. R. A. S. C.*, Nov., 1918. The lines are sharp and narrow and while the data are hardly sufficient to be conclusive, yet the present indications are that the calcium lines give a smaller range than the other lines.

27. The spectrum of this star is listed as B8. In a determination of the orbital elements (*cf. Publ. All. Obs.*, Vol 3, p. 189) by Jordan the line 4267 is listed as present and 4481 is very faint. It would seem, therefore, that the type should be B3 or earlier. All the lines, including K, are diffuse and difficult to measure. Two components are visible and Jordan makes the interesting discovery that on 10 plates near the calcium line K there is another line presumably a second calcium line which oscillates with the hydrogen and helium lines.

28. There is no orbit published for Boss 5070. Harper has the results of measures in press and from several plates he finds that H and K do not share in the large oscillation of the other lines.

29. Boss 5150 was announced as a binary from the Mt. Wilson Observatory and independently discovered as a binary here. Both observatories noted that the calcium lines differed in behaviour from the hydrogen and helium. The star is under investigation.

30. Very broad hydrogen and helium lines in this star. The calcium line K is sharp and gives a smaller range than the other lines. Both spectra show on two plates and on one plate K is doubled. It was announced from this observatory in the *Jour. R. A. S. C.*, Nov., 1918.

31. This star is an eclipsing variable. Its spectrographic orbit has been determined at this observatory by the director and the spectrum listed as A is really B2. The calcium lines are sharp and narrow and give nearly constant velocities. Both spectra, consisting of very broad and diffuse lines, are present.

32. The writer has an orbit for this star in press. All the lines are wide and diffuse save K, which is fair and gives a constant velocity. The secondary spectrum was not measured on any of the plates, though its presence was suspected. The spectrum is approximately B2.

33. An interesting feature of this star is that the velocity of the centre of mass seems to shift progressively, ranging from about —9 km in 1913 to —19 km in 1918, and the calcium lines, which give only about half the range that the hydrogen and helium lines do, show a mean

velocity which agrees from year to year with the velocity of the centre of mass. All the lines are of about the same character, being usually sharp and narrow, but they vary in character as does the amplitude of the radial velocity curve derived from measures of them. (*cf. Jour. R. A. S. C.*, Vol. 13, p. 54.)

34. This star was announced as a binary by this observatory in *Jour. R. A. S. C.*, Nov. 1918, from 4 plates. All the lines are fairly good, the hydrogen and helium give a range of about 40 km. and the present indications are that the calcium lines will show a smaller amplitude.

35. An approximate orbit for H. R. 8800 has been completed by the writer, but not yet published. The lines are of rather poor quality, and K is not very good, though better than the other lines. It seems to give an almost stationary velocity.

36. H. R. 8803 was announced as a binary from this observatory in *Jour., R. A. S. C.*, Apr., 1919. Measures of six plates gave a range of 100 km. for the hydrogen and helium lines while the calcium K gives a smaller range. All the lines are fairly sharp and narrow. There is some evidence that there are two K lines.

37. The lines in this star are wide and diffuse except K, which is very sharp and narrow. An orbit was published by the writer in *Jour., R. A. S. C.*, Vol. X., p. 297. The calcium lines are stationary, and the secondary is present, but not sufficiently strong to measure.

REFERENCES.

1. *Ap. J.*, 19, 268.
2. *Lick Obs. Bull.*, 10, 56.
3. *Ap. J.*, 51, 252.
4. *Ap. J.*, 29, 234.
5. *Observatory*, Vol. 42, p. 55.
6. *Jour. R. A. S. C.*, 14, 234.
7. *Pub. Alleg. Obs.*, 2, 70.
8. *Jour., R. A. S. C.*, 10, 359.
9. *Pub. Alleg. Obs.*, 2, 121.
10. *Pub. Alleg. Obs.*, 3.
11. *Ap. J.*, 21, 286.
12. *Lick Obs. Bull.*, 6, 156.
13. *Bull. of Nat. Obs., Argent.*, No. 1.
14. *Jour. R. A. S. C.*, 9, 423.
15. *Pub. Alleg. Obs.*, 3, 189.

THE SPECTROSCOPIC ORBITS AND DIMENSIONS OF THE ECLIPSING VARIABLES U CORONAE, TX HERCULIS AND Y CYGNI

By J. S. Plaskett.

In January-February number of this Journal (Vol. XIV., p. 1) the spectroscopic orbits and dimensions of three eclipsing variables were given. The three given here are equally interesting and of special value with the previous ones in giving us exact knowledge of the actual linear dimensions and of the masses and densities of these stars. It is proposed to observe spectroscopically at Victoria all eclipsing variables brighter than 8.0 visual magnitude for which photometric orbits have been obtained.

It may be of interest to repeat part of the introduction to the previous article showing how by combining the spectroscopic and photometric work the dimensions of these bodies can be determined.

From a series of measurements of the radial velocity of a spctroscopic binary, there can be obtained the period of revolution, the eccentricity of the orbit, the velocity of the centre of mass of the system, the amplitude of the orbital velocity, and the longitude and time of periastron. Formulæ are also available giving from the above data the semi-axis major of the orbit and an expression for the masses of the two components. Both of these dimensions, however, appear as functions of the inclination of the plane of the system to the plane tangent to the celestial sphere and, as this angle is unknown, neither the major axis nor the masses can be completely determined. Further, with respect to mass, in addition to being a function of the inclination, this appears as a function of the ratio of the masses of the two components which can only be determined in the relatively rather infrequent cases where the spectra of both bodies are visible.

The inclination of the orbit, upon which these dimensions depend, can only be obtained in two cases, in visual binaries whose orbital elements have been determined, and in eclipsing (Algol) variables for which an accurate light curve is available and the photometric orbit determined. In the case of visual binaries when both spectra can be measured the combination of data enables the masses, the major axis and the parallax to be obtained, but not the diameters nor densities of the two stars.

In the case under consideration where the stars revolve so nearly in the line of sight as to mutually eclipse one another, the photometric orbit gives the inclination, the relative dimensions of the two bodies in terms of the major axis and the densities. When, as in the three stars here discussed, both spectra are measurable, the combination of spectroscopic and photometric data furnishes complete information as to the dimensions of the systems. This is of special value owing to the very small number of stars, with these three included a total of twelve, for which such knowledge is available.

It is proposed in this paper to give a summary of the spectroscopic work only, omitting all tables and details which will appear in the publications of the observatory. At the same time all the peculiarities and interesting features of the three stars will be discussed and a final table, giving the dimensions of all the eclipsing systems which have been determined, will be given.

U Coronae.

The eclipsing variable U Coronæ, R. A. 15h 14.1m, Dec. +32° 1′ (1900), magnitude 7.5, spectral type B3, was placed under spectroscopic observation at Victoria on Mar. 25, 1919. Nine spectra were obtained and measured during the season, but press of other work and some peculiarities in the results led to the postponement of its completion until 1920. The photometric phase of these plates, with which the spectroscopic should agree, was computed from figures given by Shap-

ley in his photometric orbit, and it was found that the velocities obtained could not be fitted into these phases. In addition the spectrum of the second component was measured with certainty on four of these plates, and according to the photometric orbits this spectrum should not be visible.

These peculiarities, however, increased the interest in the system and observations were renewed on Feb. 27, 1920, and ten additional plates were obtained between that date and May 5. The difficulty of difference in phase was removed when, on looking up Wendell's original observations*, it was found there must have been a misprint or error in the initial epoch given by Shapley. However, the spectra of 1920 fully confirmed the presence of the second component, and it was measured on six of the ten 1920 plates. Although the lines of the second component are faint and difficult to measure nearly as many were used, the interagreement was fair and the probable error per plate of the measures of the secondary was not much higher than that of the primary. It appears that the secondary minimum had not been observed by Wendell and that Shapley was hence obliged to make assumptions as to the light of the fainter star giving it in five solutions a brightness varying between zero and twenty-six per cent. of the total light of the system. As it is generally assumed that the second spectrum will not appear with a greater difference than one magnitude between the components, all these orbits give too small light to the second body, and it is desirable that the secondary minimum be observed to correct the photometric results.

The spectra of the two components of U Coronæ appear to be of the same type, approximately B3, and the lines measured were H_γ, H_δ; helium 4472, 4388, 4144, 4026; magnesium 4481; carbon 4267; calcium 3934. All the lines are broad, diffuse, and lacking in contrast, with the result that the residuals of single plates are frequently high. Most of the plates were twice measured with results differing in two or three cases by 20 to 40 kms. The mean of these duplicate

*Harvard Annals, 69, p. 76.

measures, weighted where deemed desirable, was used. Two of the plates were discarded, one too weak and the other so near minimum that blending of the component spectra was to be feared.

The orbit was determined in the usual way by least-squares correction of graphical preliminary values. A plot of the nine normal places derived from the seventeen measures in the accompanying velocity curve, Fig. 1, shows that the orbit is circular and the difference between photometric and spectroscopic phases so small that, when the uncertainty of the measures and their position generally near the maximum velocities is considered, no correction to phase is necessary. Hence the correction is quite simple and resulted in the following values for the elements.

Period (photometric)	P	=3.4522269 dys
Velocity of system	γ	= −7.5± 1.7 km per sec.
Semi-amplitude bright star	K_1	= 69.5± 3.1 " " "
" " faint "	K_2	= 181.9± 4.2 " " "

The probable error of the velocity of a single plate for the bright star is ± 8.5 and for the faint ± 11.4 km per sec.

In view of the appearance of the second spectrum the choice of the five photometric solutions given by Shapley* should evidently be No. 4, in which the faint component is assumed to have the greatest brightness, twenty-six per cent. of the light of the system. Although the ratio of brightness is probably somewhat greater, the other solutions, in which the brightness of the faint star is given different values between zero and fourteen per cent, show that little error in the dimensions is thereby introduced. From this photomtric orbit the inclination of the orbit plane is 81° 23′, and the radii of the bright and faint components .167 and .273 respectively of their separation.

*Contributions from Princeton Observatory No. 3, p. 86.

The well known formulæ give, from the spectroscopic orbit.

$a \sin i = 11{,}940{,}000$ km, hence $a = 12{,}080{,}000$ km $= 17.36$ ⊙

$(m_1+m_2) \sin^3 i = 5.7$ ⊙, hence $m_1+m_2 = 5.9$ ⊙

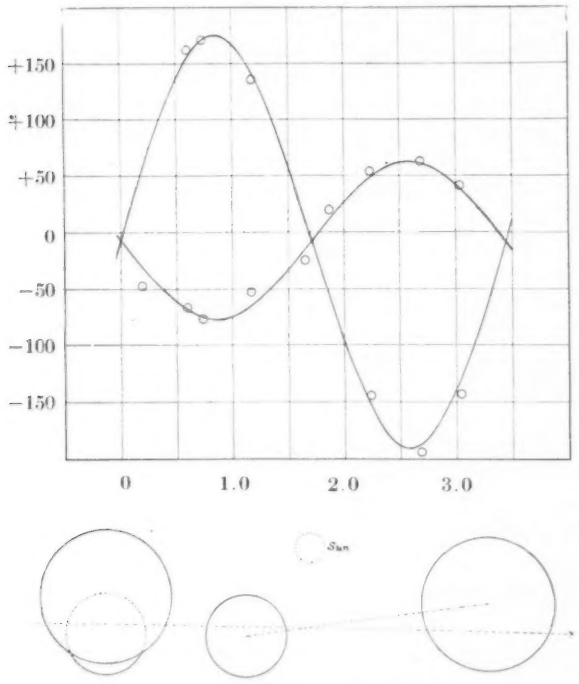


FIG. 1.—Velocity Curve and Relative Dimensions of U Coronae.

Hence combining photometric and spectroscopic data we have:

Separation of two stars	a	$= 12{,}080{,}000$ km	$= 17.36$ ⊙
Semi-axis orbit bright star	a_1	$= 3{,}339{,}000$ km	$= 4.80$ ⊙
" " " faint "	a_2	$= 8{,}741{,}000$ km	$= 12.56$
Radius bright star	r_1	$= 2{,}017{,}000$	$= 2.90$
" faint "	r_2	$= 3{,}298{,}000$	$= 4.74$
Mass bright "	m_1		$= 4.27$
" faint "	m_2		$= 1.63$
Density bright "	ρ_1		$= .175$
" faint "	ρ_2		$= .015$

Assuming according to Shapley* the surface intensity of a B3 star to be -2.7 magnitudes as compared with the sun whose absolute magnitude is taken as 4.86, the absolute magnitude of the bright component of U Coronæ whose apparent magnitude is 7.85 is -0.15 and the parallax is 0".0025.

There is one point here to which attention should be drawn, and that is the relative surface intensity of these two stars. The parallax obtained above is based on the assumption that the surface intensity of a star is a function only of the temperature and the similar assumption that the spectral type is also governed by the temperature. In U Coronæ, as the two components have the same spectral type, their surface intensities should be equal, but in reality the primary has several times the surface intensity of the secondary, eight times if its light is twenty-six per cent of the light of the system. In R.S. Vulpeculæ previously determined† where the spectra of the components were of practically the same type, the brighter star had twenty-eight times the surface intensity of the fainter and the same thing is probably true of many other eclipsing systems. It appears certain, therefore, that in Algol binaries the surface intensity is not wholly a function of temperature or spectral type, but that some other factor, possibly density, enters.

Although the character of the spectral lines in U Coronæ is such as to prevent accurate velocity measures, still the range is so great as to ensure fairly accurate relative values and elements as indicated by the probable errors. The dimensions of the system are probably correct within five per cent. The figure, Fig. 1, shows the velocity curves of the two components with the normal places plotted as circles and below the relative dimensions of the system as compared with the sun.

TX Herculis.

The eclipsing variable TX Herculis, R. A. 17h 15.4m, Dec. $+42°$ 0′, magnitude 8.0, spectral type A2, whose photometric

*Astrophysical Journal 40, p. 412.

†This JOURNAL, 14, p. 1.

orbit has been computed by Shapley* from observations by Lazzarino is, however, classified by him as of the third grade only. Shapley assumes the period to be double that given by the observer with equal primary and secondary minimum, and the spectroscopic observations show the truth of this assumption and confirm the general correctness of the photometric orbit.

TX Herculis was placed under observation on March 17, 1920, and sixteen plates were intermittently obtained between that date and Aug. 13, of which fourteen were used in obtaining the orbit, the remaining two occurring so near the minima as to be affected by blending of the spectral lines from the two stars, with a resulting unreliable velocity. The spectra, for lines of both components are present, are of type A2 with numerous sharp lines, and are easily measurable. The lines of the principal or brighter star are, however, considerably stronger and better defined than those of the secondary with resulting more reliable velocity values. The star is faint, 8.0 visual magnitude at maximum, and some of the plates are rather weak. If the seeing is good one hour's exposure gives a good spectrum of linear dispersion 29A per mm at H_γ but this has to be considerably increased if the seeing is poor.

The plotting of the observations on cross section paper, the phases being determined from the initial phase 2,418,967.3925+2.059786 days used by Shapley, shows in Fig. 2 that they would be satisfied by a circular orbit with no likelihood of any eccentricity as some of the photometric work seems to indicate. There is, however, a displacement of phase, the spectroscopic occurring later than the photometric, and a further anomaly in an apparent difference in the systematic velocity for the two components, the observations being best satisfied with about —8 km per second for principal and —3 km for secondary components. However, such a condition is impossible, and there must have been something in the character of the spectral lines of the second component which are much weaker, more diffuse, and less accurately

*Contributions from Princeton Observatory, No. 3, p. 88.

measureable than those of the principal star which caused this apparent displacement.

The elements determined graphically from the velocity curve and corrected by least squares, a co-efficient being introduced in this star for phase gave the following values:

Period (photometric)	P	=2.059786 days
Velocity of system	γ	= −6.4±1.0 km. per sec.
Semi-amplitude bright star	K_1	=121.0±1.0 " " "
" " fainter "	K_2	=140.2±2.4 " " "
Time of spectroscopic phrase	T	=.0415±.0049 days (later than photometric).

From the computed residuals the probable error of measurement of a single plate is±2.6 km per second for the principal star and ±7.5 for the secondary.

Using Shapley's darkened orbit as the most probable which gives the radius of each sar as .125 their separation and the inclination of the orbit plane as 86° 16′, we obtain from the spectroscopic elements by the well known formulæ:

$a \sin i = 7.397{,}000$km, hence a = 7,413,000 km = 10.66.
$(m_1+m_2) \sin^3 i = 3.78.$, hence $m_1+m_2=$ 3.81.

Combining spectroscopic and photometric data we have

Separation of two stars	a	=7,413,000 km = 10.66.
Semi-axis orbit bright star	a_1	=3,447,000 " = 4.96
" " " faint "	a_2	=3,966,000 " = 5.70
Radius of each star	r	= 927,000 = 1.33
Mass principal star	m_1	= 2.04
" secondary "	m_2	= 1.77
Density principal star	ρ_1	= 0.87
" secondary "	ρ_2	= 0.75

Again using a similar assumption, of —1.8 magnitudes, as the surface intensity of an A2 star we have the absolute magnitude of the principal component of TX Herculis as 2.44, while its apparent magnitude is 8.73. The well known formula for parallax makes this quantity 0″.0055.

The orbit is simple and with no difficulties save the apparent differences of about 5 km per second in the systematic velocities of the two components. This discrepancy is probably mostly due to the lines of the second component which are relatively poor, and in which some slight asymmetry may easily shift the measured position by the small amount re-

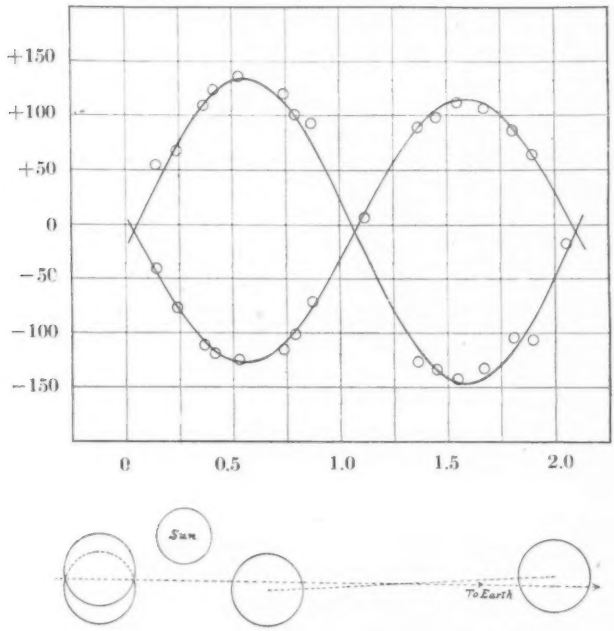


FIG. 2.—Velocity Curve and Relative Dimensions of TX Herculis.

quired, 2.5 microns on the plates. The displacement of phase, the spectroscopic being an hour later, in the same direction as in RS Vulpeculæ and TW Draconis, but in the opposite direction to the displacements found by Schlesinger seems certainly in this case most likely due to errors in the photometric data. If the photometric period were changed by an amount of the order of one one-hundred-thousandth of a day, about

one second, this would be suffcient, when carried forward from the initial epoch, to account for the displacement found. The spectroscopic observations determine the phase with a probable error of seven minutes, so that the deviation of one hour seems more likely to be due to error in the photometric period especially as in this star the observations are somewhat uncertain.

The relative dimensions of the system with respect to the sun are shown in Fig. 2 below the velocity curve.

Y Cygni.

The eclipsing variable Y Cygni, R. A. 20h 48.1m, Dec. +34° 17′ (1900), spectral type B2, magnitude 7.0, has been widely observed for light variations since its discovery, but the observations are scattered and disconnected, and the light curve or curves are in an unsatisfactory state. This difficulty is mainly due to the period which differs by only five minutes from three days. Consequently, only a small part of the cycle can be observed in any one season and observations over several seasons would be required to entirely cover the period.

Dunér, in 1900, determined an elaborate photometric orbit* for this star, which gave it an eccentricity of 0.145, very high for such a close pair, with a secular change in the elements. Later observations did not agree with these elements, and in 1914 Shapley determined another photometric orbit†, using Dunér's period and Wendell's incomplete observations. This orbit was circular, and so far as the present incomplete spectroscopic results can determine, Shapley's orbit seems more nearly correct that Dunér's.

Evidently spectroscopic observations will be attended with the same difficulty of distribution over the cycle as photometric, but in pursuance of a programme of obtaining orbits of all eclipsing variables brighter than the eighth magnitude and within reach at this latitude, this star was placed under

*Ap. Jr., 11, p. 175.

†Contributions from Princeton Observatory, No. 3, p. 88.

observation on Aug. 6, 1919, and between that date and Aug. 9, 1920, twenty-four spectra were obtained, all of which have been measured. Nineteen of these plates were used in determining the orbit, the remaining five being too close to the minima with consequent blending of the lines of the components to be safely used.

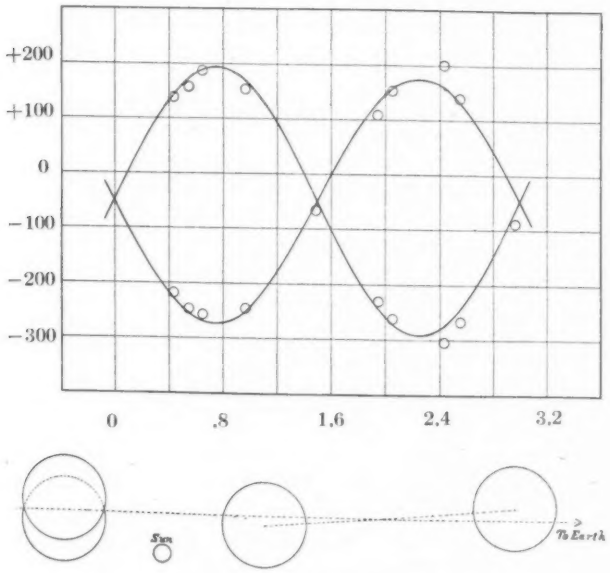


Fig. 3.—Velocity Curve and Relative Dimensions of Y Cygni.

The spectra, for both components of practically equal intensity are visible, are exceedingly difficult to measure as the lines are not only very broad and diffuse, but are also very faint and lacking in contrast and in many cases are barely visible under the microscope, and the positions can only be measured under very low magnification. This lack of contrast is probably partly due to the superposition on the absorption line of the one star of the continuous spectrum of the equally bright companion, thereby reducing the contrast which is never very

great, as the plates taken at minimum, when most of the light is from one star only, clearly show. The breadth of the lines may possibly be due to axial rotation of these bodies, which is likely to have the same period as their revolution. The spectral type given as A is in reality so far as can be judged from the diffuse and faint lines B2. Sharp single calcium H and K lines are present, as is so often the case with diffuse-lined B-types, and these lines are practically stationary, do not share in the large oscillations of the hydrogen and helium lines, and give a widely different value for the velocity of the system. The character of the hydrogen and helium lines and the uncertainty of measurement may be judged from the high probable errors of a single plate which amount to ± 17.2 and ± 16.0 km per second for the principal and secondary components. Nevertheless, owing to the great range the separation of the component lines being nearly 500 km at maximum, the error in the dimensions of the system cannot be relatively great. The lines measured have included hydrogen $H\beta$, $H\gamma$, $H\delta$; helium 4472, 4388, 4144, 4026; magnesium 4481; carbon 4267; calcium H and K. None of the other helium lines or of the lines of other elements usually present in stars of this type are visible.

The 19 observations were collected into 8 normal places which are plotted in the velocity curve of Fig. 3, while the 5 not used in the orbit were combined into 2 places near minima also plotted on the curve. This plot showed to the order of accuracy of the observations that the spectroscopic orbit was circular, and that spectroscopic and photometric phases agreed. Preliminary elements were obtained graphically and corrections to the amplitude of primary and secondary and to the velocity of the system were obtained by least squares, resulting in the following elements:

Period (photometic)	$P = 2.996332$ days
Semi-amplitude primary star	$K_1 = 223. \pm 4.1$
" " secondary "	$K_2 = 242.5 \pm 4.0$
Velocity of system	$\gamma = -49.1 \pm 2.3$

The orbit, although probably as good as can be obtained from spectra with such diffuse lines cannot be considered as entirely satisfactory and final, in the first place because the cycle is only incompletely covered and the second because of the high residuals of normal place No. 8, the third from the last in the velocity curve, where the separation of the lines of the components is about 70 km per second greater than required by the orbit. These plates were remeasured, and although the lines are very diffuse they are at least as good as at other phases, and I believe the increased separation is a real phenomenon, not due to error of measurement, and that further observations should be obtained in future seasons to fill up the gaps in the cycle and enable the cause of this discrepancy to be determined. It might be attributed to eccentricity such as Dunér found were it not that all other parts of the curve follow a circular orbit quite as closely as the character of the spectra and the accuracy of the measures warrant.

Another interesting feature is the behaviour of the narrow sharp calcium H and K lines which have been measured in all spectra strong enough to show them distinctly, but which were not, for obvious reasons, used in the orbital determination. There can be no reasonable doubt that these lines are stationary in position as the probable error of the measurement of the K line is only $\pm$ 2.2 km per second on this assumption. The velocity of the system from the sharp calcium lines is—10.7 $\pm$0.7 km per second a difference of nearly 40 km per second from that obtained from the diffuse lines, a much larger difference than usually found in similar stars. Dr. Young has recently collected all the available data concerning the sharp calcium lines in diffuse lined B-type binary or single stars, and concludes that the calcium vapour is connected with and moving with the star. He finds in general the difference in the velocity from the calcium lines and from the other lines is negligible when the character of the latter is consideed. He explains the discrepancy where present by considering that the same cause which makes the lines diffuse may shift their center of intensity the required small amount. Although it is

difficult to see how so great a difference as 40 km when the probable error of γ is ± 2.3 km per second can be accounted for in this way, there is no denying that a systematic velocity of -49 km for such a massive B star as this is very much higher than can reasonably be expected.

There remains to combine the spectroscopic and photometric data for obtaining the dimensions of the system. Notwithstanding the uncertainty of the measures, leaving out of consideration the abnormal features discussed above, the probable errors indicate that the dimensions should be correct to two per cent. It is evident also, as the discrepant normal place indicated a greater amplitude, that we are obtaining in any case the minimum probable dimensions of this exceedingly massive system. According to Shapley's darkened orbit the inclination of the orbit plane is 84° 57′, and the radius of each star .166 of their separation. From the spectroscopic data

$$a \sin i = 19{,}220{,}000 \text{ km}, \quad (m_1+m_2) \sin^3 i = 31.57 \odot$$

Hence combining photometric and spectroscopic data we obtain

Separation of two stars	$a = 19{,}294{,}000$ km	$= 27.7 \odot$
Radius of each star	$r = 3{,}216{,}000$ "	$= 4.6$
Mass principal star	$m_1 =$	16.6
Mass secondary star	$m_2 =$	15.3
Total mass system	$m =$	31.9
Density principal star	ρ_1	.170
Density secondary star	ρ_2	.158

Assuming as above that the surface intensity of a B2 star as compared with the sun is —2.8 magnitudes, the absolute magnitude of the principal component is —1.25. Its apparent magnitude is 7.7, and by the usual formula its parallax is 0″.0016. The relative dimensions and positions of this system, one of the two or three most massive known, are given in Fig. 3. This orbit should not be considered final, as it is proposed to obtain further spectroscopic observations which, when

combined with photometric work now, it is understood, being undertaken should enable more complete information about this very interesting system to be obtained.

In conclusion, it will be of interest to tabulate the dimensions of all eclipsing systems known to the writer in which the spectra of both components have been observed, and in which consequently, values reliable within the errors of observation and subject to no uncertain assumptions, have been obtained. This table gives the name and spectral type of the variable, the radii of the two components and distance of the centres in terms of the sun's radius; and the masses and densities of each in terms of the sun's mass and density:

ABSOLUTE DIMENSIONS OF ECLIPSING VARIABLES

Star	Type	Radii		Masses		Densities		Distance of Centres
		r_1	r_2	m_1	m_2	ρ_1	ρ_2	a
β Aurigae[1]	Ap	2.81	2.81	2.40	2.36	0.11	0.11	17.7
U Herculis[1]	B3	4.56	5.35	7.66	2.93	0.095	0.022	14.8
V Puppis[1]	B1,B3	8.45	7.70	19.4	19.4	0.042	0.055	12.7
β Lyrae[1]	B8,B5	16.2	40.6	1.42	14.2	0.0006	0.0004	59.9
RX Herculis[2]	B9	1.54	1.38	0.89	0.89	0.25	0.34	7.47
W Ursae Majoris[3]	G	0.78	0.78	0.69	0.49	2.8	1.9	2.2
Z Herculis[4]	F	1.77	3.29	1.6	1.3	0.3	0.04	15.1
U Ophiuchi[5]	B5	3.23	3.23	5.36	4.71	0.18	0.16	12.8
RS Vulpeculae[5]	B8,B9	2.05	10.25	5.40	1.69	0.63	0.0016	22.0
U Coronae	B3	2.90	4.74	4.27	1.63	0.175	0.015	17.36
TX Herculis	A2	1.33	1.33	2.04	1.77	0.87	0.75	10.66
Y Cygni	B2	4.60	4.60	16.6	15.3	0.170	0.158	27.7

[1] *Ap. J.*, 28, p. 169.
[2] *Ap. J.*, 40, p. 399.
[3] *Ap. J.*, 49, p. 189.
[4] *Ap. J.*, 49, p. 192.
[5] *Jour. R. A. S. C.*, 14, p. 1.

It is of interest to call attention to the progression of increasing spectral type with decreasing mass the early B's being on the average six times as massive as the later types. A similar

relation has been previously referred to by several investigators, but most recently by Ludendorff* in an investigation of the masses of spectroscopic binaries. The latter finds, assuming the inclination of the orbit planes the same on the average for all types, that the masses of spectroscopic binaries of type Bo to B3 are about 2.5 times as great as those of type A and 4 times those of type F. There are insufficient data for the O, G and K types, but so far as it goes, it indicates the O's are considerably more massive than the B's, while the K's may be less massive that the F's. There seems to be a real progression shown which, so far as it goes, is confirmed by the above dimensions, and which is of great interest and importance in its bearing on the question of stellar evolution.

Dominion Astrophysical Observatory,
Victoria,B.C.,
September, 1920.

*A. N. 5046.

THE FESTIVAL OF THE DEAD

By R. G. Haliburton

(*Continued from page 376*)

the question, what made November the month of Death, or of the God of the Dead, among the Peruvians, the Fijians, the Persians and the Egyptians, and to this day the month of *Fear* among the Arabs; and why do we find funereal celebrations held in it in so many countries, north as well as south of the equator,—in the old world as well as in the new,—by the most civilized and the most savage races of the present day, as well as by nations of the most remote antiquity?

"The inference from this state of the case is, or ought to be, as certain and spontaneous as that from the other:—That, if mankind have always been using, and are still using, the same calendar, they must have had the same origin. Nothing will account for it but the fact that men themselves have everywhere had a common origin; and have derived their calendar everywhere from the same source as their being itself." (Fasti Cath., i. 690.)

CONCLUSION.

In treating of the primitive year and the festival of the dead, I have endeavored to restrict my researches to the connection of this commemoration with the calendar by which it was regulated. Whether I am right or not in my conjecture, as to a migration of races from the south, is not material as respects the main object of this paper; though I believe that it will at least prove correct as regards the Egyptians and many other ancient nations, among whom this festival was invested with a veil of mystery, beneath which, however, it is easy to trace the Fijian god of the world of spirits presiding over the November festival of agriculture and of the dead, and to recognize the belief of some of the wild tribes of South America as to the Great Father, who residing in the Pleiades, sinks beneath the world with "the Pleiades below," and rises to light with "the Pleiades above." [1]

I have already shown that "le taureau mis à mort et resuscité," which was typified, as Dupuis asserts, in all the ancient mysteries, represented this death and revival of the stars in Taurus; and that the myth of Osiris (whose soul resides in a *Bull*) being lost and found in November, and of Proserpine (the daughter of Ceres and a *Bull*) sinking down into hell and rising again; as well as the two festivals of the German Goddess of Life and Death, all had their origin in the appearance and disappear-

[1] It has been shewn that the Fiji god comes up in November from the world of spirits to make the fruit trees to blossom, and that the same superstitions that were attached by the Romans to the *mundus patens*, or to Pluto unlocking the gates of Hades, are to be found among the Fiji Islanders connected with their god. We can best judge of the identity of the two deities by examining the following hymn addressed to Pluto, in which we find him represented as the janitor of the world of spirits and the God of Agriculture, and of the Dead. It would equally apply to the Fiji deity, the Lord of *Pulotu* (Turner's Polynesia, p. 38, 237. See ante, p. 23, **33, 51,** 72, note):

"Pluto, magnanimous, whose realms profound
Are fixed beneath the firm and solid ground,
In the Tartarean plains remote from sight,
And wrapt forever in the depths of night.
Terrestrial Jove, thy sacred ear incline,
And pleas'd accept these sacred rites divine.
Earth's keys to thee, illustrious king, belong,
Its secret gates unlocking, deep and strong;
'Tis thine abundant annual fruits to bear,
For needy mortals are thy constant care."

—The Mystical Hymns of Orpheus, translated by T. Taylor, p. 52.

ance of the stars in Taurus.[2] That the initiated at the ancient mysteries really learned something as to the astronomical basis of their religion, we have every reason to infer; but it is plain that Herodotus and many other ancient authors were either ignorant, or prudently silent as to the secret sources of classical mythology.

Chæremon and others, however, according to Eusebius, not only believed, but also declared that the Egyptians held that the stars were the only deities, and that all festivals had been instituted originally in their honor; that "the heroes whose names appear in the almanacs, are nothing else than charms for the cures of evils, and *observations of the risings and settings of stars.*" They also believed "that the *legends about Osiris and Isis and all other their mythological fables have reference either to the stars, their appearances and occultations,* and the periods of their risings, or to the increase and decrease of the moon, or to the cycles of the sun, or to *the diurnal and noctidiurnal hemispheres.*" [3]

It is therefore plain that my conclusions, based on the times of observance of festivals and on their connection with the year of the Pleiades, are borne out by the opinions of the ancients themselves. But their view of the astronomical character of Egyptian mythology, supplies a clue to what has hitherto evaded all enquiry. If the very deities of the Egyptians were merely representatives of the stars, and of the year, then their symbols must also have had a hidden meaning connected with the year or its seasons. The *crux ansata,* or the T or *tau,* surmounted by a ring, and the sacred beetle, the *scaraboeus,* were the most mysterious and the most conspicuous emblems of the Egyptians. I have found that they were in reality the same. In seeking for the meaning of the scarabæus, it has escaped notice that it was the hieroglyphic for the letter T, and that its Egyptian name was *Thore.* On examining a scarabæus in my possession, I found out the reason for its name, and of its significance. On the back of the beetle a T or Tau is most clearly marked.

A friend to whom I mentioned this fact, informs me that these are the natural marks on the Egyptian beetle; and my discovery suggested to him an interesting fact that the same species is still popularly known in England as the *Tor* or Tau beetle.

[2] I have already shown that the "finding of Osiris" did not take place in Pachons, but in Athyr. Sir Gardner Wilkinson has adopted a meaning of a passage in Plutarch, which Gebelin and others have pronounced to be incorrect. Greswell connects the myth of Proserpine and her autumn festival with the Isia. See Gebelin le Monde Primitif. Fasti Cath., ii. 455, 458; iii. 135; iv. 29.

[3] Eus. Pr. Evan., iii. c. 4. See Cory's Ancient Fragments of Phoenician, Chaldaean, Egyptian and other writers, p. 288.

To be continued [91]

NOTES FROM THE DOMINION OBSERVATORY, VICTORIA, B.C.

MEETINGS OF THE SEMINAR

BY J. S. PLASKETT.

At a meeting of the staff of the Observatory in November 1919 it was decided to form a seminar and to hold informal meetings about once every two weeks for the purpose of discussing subjects of current interest in Astronomy. Although it was proposed in the first place to confine the discussions to reviews of single articles in the various astronomical periodicals, the scope of many of the meetings, as will be seen in the list of subjects, was enlarged to cover whole subdivisions or phases of astronomical progress. One example of this development is the paper "Origin of Spectra" by H. H. Plaskett which recently appeared in this JOURNAL and many of the subjects discussed have formed comprehensive reviews of recent developments in the Science.

These meetings have proved exceedingly useful, keeping the members of the observatory staff in close touch with the different phases of astronomy and inviting discussion and research into many problems which, in the ordinary course of the work, would not have arisen. The plan followed has been for each member of the staff in turn, at intervals of about two weeks, to select a subject for discussion, prepare a paper on it and present it at an afternoon meeting. These meetings are quite informal and friendly, no one feeling the slightest hesitation in asking questions or precipitating a discussion during the presentation of the matter, with the result, as generally admitted, of making the meetings of the greatest possible value and interest.

These meetings have been so much enjoyed and everyone has derived so much benefit from the discussions that there has not been the slightest appearance, as so often happens in similar attempts, of loss of interest. With four astronomers no one has to prepare a paper oftener than once every two months and although this preparation involves considerable work, it is well repaid by

the grasp of the subject obtained by the one preparing as well as the much clearer knowledge obtained by those listening than is possible by even a careful reading of the literature on the subject.

The following is a list of the subjects discussed since the inauguration of the meetings.

PAPERS READ AT SEMINAR

1. Spherical Aberration and the Form of Star Images
   (Conrady M.N. 79, No. 8) by J. S. Plaskett.
2. Variable Stars with more Particular Reference to Cepheid Variables
   by W. E. Harper.
3. The Parallaxes of the Brighter Helium Stars
   (Ap. J. 47, 1918, March, April, May, by J. C. Kapteyn)
   by R. K. Young.
4. Radiation and Quantum Theory by H. H. Plaskett.
5. Spectral Classification of the Stars by J. S. Plaskett.
6. Cepheid Variation by W. E. Harper.
7. On the Motions of the A-type Stars in Relation to the Milky Way
   (L.O.B. No. 212, Vol. 7. by H. C. Plummer) by R. K. Young.
8. Origin of Spectra by H. H. Plaskett.
9. Shapley's Investigations of Star Clusters by J. S. Plaskett.
10. Giant and Dwarf Stars by W. E. Harper..
11. H and K Lines in the Early B-type Stars by R. K. Young.
12. A New Method of Spectrophotometry by H. H. Plaskett.
13. Structure and Dimensions of the Universe by J. S. Plaskett.
14. "Studies of the Nebulae"—A Review
    (Vol. XIII Publications Lick Observatory) by W. E. Harper.
15. The Problem of the Short Period Variables
    (M.N. Vol. 80, 496. M.N. 73, 658 by H. C. Plummer) by R. K. Young
16. Stellar Evolution (A Review of Jeans' Problems of Cosmogony)
    by H. H. Plaskett.
17. Masses of Spectroscopic Binaries
    (Ludendorff A.N. No. 5046) by J. S. Plaskett.
18. The Work of the Union Observatory, Johannesburg by W. E. Harper.
19. Distribution of the Stars in Space
    (Ap. J. July 1920. by J. C. Kapteyn and P. J. Van Rhyn)
    by R. K. Young.
20. The General Magnetic Field of the Sun by S. L. Boothroyd
21. Intensity Distribution in Typical Stellar Spectra by H. H. Plaskett.

NOTES FROM THE METEOROLOGICAL SERVICE

OCTOBER, 1920.

TEMPERATURE

The temperature was from average to three degrees below in British Columbia and in Western Alberta, elsewhere in the Dominion it was above the average. The positive departures ranged from 4° to 8° in Ontario, from 3° to 5° in the Maritime Provinces and from 2° to 5° in Saskatchewan and Manitoba.

TEMPERATURE FOR MONTH OF OCTOBER, 1920

STATIONS	OCTOBER		STATIONS	OCTOBER	
	Highest	Lowest		Highest	Lowest
Yukon			*Ontario—continued*		
Dawson	38	14	Kenora	76	14
British Columbia			Kinmount	—	—
Atlin	46	10	Kitchener	77	30
Agassiz	63	30	Kingston	70	32
Barkerville	61	13	London	80	29
Kamloops	53	28	Lucknow	79	27
New Westminster	59	32	Markdale	—	—
Prince Rupert	59	30	North Gower	73	27
Vancouver	57	32	Oshawa	80	30
Victoria	59	37	Ottawa	75	30
			Paris	83	31
West Provinces			Parry Sound	76	29
Battleford	78	22	Peterborough	82	30
Calgary	84	15	Port Arthur	75	23
Edmonton	72	15	Port Burwell	74	32
Medicine Hat	85	25	Port Dover	76	32
Minnedosa	84	18	Port Stanley	80	29
Moosejaw	88	22	Queensborough	76	26
Oakbank	83	26	Ronville	76	27
Portage la Prairie	84	22	Southampton	79	34
Prince Albert	80	18	Sundridge	—	—
Qu'Appelle	85	19	Stonecliffe	82	16
Regina	86	18	Stoney Creek	81	33
Saskatoon	82	18	Toronto	81	33
Souris	90	23	Uxbridge	78	29
Swift Current	79	22	Wallaceburg	73	30
Winnipeg	82	16	Welland	76	32
			White River	74	1
Ontario					
Agincourt	—	—	*Quebec*		
Oak Ridges	79	28	Brome	70	25
Bancroft	78	47	Father Point	64	26
Barrie	77	29	Montreal	71	31
Beatrice	77	26	Quebec	67	29
Bloomfield	73	30	Sherbrooke	72	29
Brantford	—	—			
Chapleau	—	—	*Maritime Provinces*		
Chatham	—	—	Charlottetown	68	32
Clinton	75	28	Chatham	72	32
Collingwood	85	31	Dalhousie	—	—
Cottam	82	30	Fredericton	73	29
Georgetown	77	28	Halifax	74	32
Goderich	—	—	Moncton	75	29
Gravenhurst	81	30	St. John	67	35
Grimsby	78	33	Sussex	75	25
Guelph	77	28	Sydney	74	30
Haliburton	78	27	Yarmouth	70	30
Huntsville	82	26			

Precipitation

The precipitation was much above the usual quantity in British Columbia; it was also above in Alberta and Saskatchewan. In Manitoba it was above in some districts while in others there was very little. In Ontario it did not attain to the average amount except locally, the excess being chiefly confined to places situated in the Peninsula. In Quebec some districts recorded less than the normal amount while in others the average was exceeded. In the Maritime Provinces, except locally in Northern New Brunswick there was very little precipitation. Some of the most marked positive departures were Vancouver, 2.70 inches; Barkerville, 3.20 inches; Quebec, 2.20 inches; Anticosti, 3.10 inches. Noticeable negative departures were Yarmouth, 3.60 inches; Halifax, 4.10 inches; Charlottetown, 3.80 inches; Sydney, 4.50 inches.

Magnetic Disturbances

September 1920.

During the month of September there was much greater activity in the earth's magnetic field than for some time past. Only three days were classed as calm at Agincourt, whilst six days were much disturbed. The following table gives the general information relative to the disturbances.

September Disturbances

	Beginning			Ending			Agincourt Range H	Agincourt Range Z	Agincourt Range D	Meanook D
	day	hour	min.	day	hour	min.	γ	γ	′	′
I.	2	23	50	5	5	—	210	232	50.6	136.9
II.	8	4	—	9	7	—	306	269	46.2	153.2
III.	21	21	15	23	2	—	322	237	27.1	78.4
IV.	28	5	30	29	10	—	826	573	117.0	176.5

The most important of these disturbances was the fourth. Beginning rather sluggishly in the early morning of the 28th the needle moved slowly westward and the force gradually declined up to 10 o'clock. The force then began to increase slowly and the needle to swing back eastward until 14 hours when the movements became very violent, the horizontal force record passing beyond the upper limit of the recording apparatus. The maximum force was reached about 14 hours in both the horizontal and vertical,

and a decline commenced, with however rapid fluctuations, which carried the force to a minimum about 2 a.m. of the 29th. Following this the turn to normal was fairly rapid in all three elements.

At Meanook the general movements were somewhat similar in the declination, but the small rapid pulsations were more pronounced and the amplitude much larger.

The aurora was also much more pronounced during September and the greatest frequency coincided with the times of magnetic activity. The aurora of the 28th and 29th was reported from all parts of Canada as of the 1st class and very brilliant.

Sunspots were very active, although on the 17th and 18th none were visible. Large groups were central on the sun's disk on the 2nd, 12th, and 28th, and a new group was developing in the northwest quadrant of the 13th.

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH, TORONTO

P.T.—Preliminary Tremors. S.—Secondary Waves. L.—Large Waves. A.C.—Air Currents
Time is Greenwich Mean Civil Time; it is to be given in hours, minutes and decimals of minutes
0 or 24 h—midnight.

SIR FREDERIC STUPART, F.R.S.C., DIRECTOR

No.	Date 1920. October	P.T. Comm. h m	S. Comm. h m	L.W. Comm. h m	Max. h m	End h m	Max Amp mm	Remarks
	1st	Light off	at 19: 06	to 19: 10.	Quake	missed .a	ttendin	g inst.
2195.	7th		21 09.0	21 17.4	21?18.8	Micros.	0.6	Marked micros going on.
2196.	8th		?17 04.5	17 08.8	17 09.9	Micros.	0.4	Small micros going on.
2197.	12th			7 53.9		7 56.9	0.1	
2198.	15th			14 54.5		14 57.5	0.2	
2199.	18th	?826.4	8 34.7	8 42.8 8 58.4	?9 05.9	9 56.7	1.0	Faint record.
2200.	18th			13 12.9 13 20.1	13 22.1		0.4	Faint trace.
2201.	20th			11 07.6	11 10.5	11 28.5	0.3	
2202.	22nd			12 05.7		12 08.8	0.1	May not be seismic.
2203.	22nd		12 29.5		12 31.7	13 30.1?	1.2	P indistinct.
2204.	24th			2 34.1 2 42.2	2 43.0		0.2	
2205.	26th			19 25.8		19 28.8	0.2	
2206.	28th			7 59.2	8 01.1	8 25.5	0.3	
2207.	28th	13 01..2	13 11.0	13 25.5	13 12.1	14 08.1	0.8	8560 Km. Quake in Chili. Max.. occured during S waves. SR1—1315.9 SR2—1319.7

Period of Boom 18 seconds. Pillar inclination 1 mm—0.45

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH, VICTORIA, B.C.

F. NAPIER DENISON, SUPERINTENDENT

No.	Date 1920	P. T. Comm.	S. Comm.	L. W. Comm.	Max	End	Max Amp.	Remarks
	October	h m s	h m s	h m s	h m s	h m s	mm	
					19 12 37	19 21 28	1.0	1400 Km
2191	1	19 10 10						
				19 10 51	19 12 49	19 17 15	0.4	Pender Is. reported a quake at 12.35 p.m. Pac. Stan. Time.
2192	5							
2193	7	21?06 18	21 15 53	21 29 10	21 34 05	22 35 27	0.5	
2194	8		17?07 47	17?12 17				
				17 14 29	17 17 05	17 37 23	0.3	
				7 47 23	7 53 46	7 58 41	0.2	
2195	12	7 43 56		14?56 12	14 58 40	15 07 02	0.5	
2196	15							
2197	18	8 15 58	8 21 02	8 28 25	8 36 46	10 03 20	1.0	3170 Km.
2198	18	12 14 00			12 15 14	12 17 27	0.2	
2199	18	12 52 20			12 53 19		0.5	Merged into next quake. 450 Km.
2200	18	13 01 12			13 02 41	13 12 01	1.0	660 Km.
2201	20	10 43 12			11 00 25	11 33 22	0.2	
2202	22		12 33 00	12 48 10	12 57 35	13 43 20	0.5	S may be L phase.
	23	Clock sto	pped, sm	all quake	possibly	missed,	morni	ng of 24th.
2203	26	19 30 29		19 31 58	19 33 26	19 34 25	0.2	
2204	28			7 36 31	7 44 23	8 29 38	0.4	
2205	28	13?05 06	13 12 58		13 13 57		0.5	S may be L phase.
		13 08 03						
2206	28	13 31 39		13 35 35	13 40 01	15 20 50	1.1	

Period of Boom 18 seconds. Pillar inclination 1 mm = 0.″54.

BOOK REVIEWS

Cours d'Astronomic; partie général élémentaire par Maurice Alliaume, professeur a l'Universite de Louvain. Louvain, A. Uystpruyst-Dieudonné. Paris, Gauthier-Villars. 368 pages, 6x9 in., 1920.

Où en est la Météorologie par Alphonse Berget, Paris, Gauthier-Villars. 300 pages, 5x7¾, 1920.

The first of the above volumes was written specially for students in the elementary course in astronomy in the University of Louvain, and is intended as a preparation for advanced work in mathematical astronomy and celestial mechanics. It is also taken by senior students in engineering and provides a scientific basis for topographical work.

After a preliminary chapter dealing with co-ordinates and their transformations, there follow the three divisions of the course, referring to the points chosen as origin of co-ordinates, namely: part 1, the eye of the observer; part 2, the centre of the earth; part 3, the centre of the sun. Each of these is subdivided into sections and propositions conveniently arranged for assigning tasks to students and also for the purpose of formal examinations. One is reminded of Barlow and Bryan's *Elementary Mathematical Astronomy* though the new work demands much higher mathematical attainments.

The second volume is one of a "Collection des Mises au Point". The operations of the war showed the importance of a knowledge of our atmosphere, and the present work is an attempt to state the present state of the study of meteorology in the hope that further attention may be given to it and it may become an exact science. The various atmospheric phenomena are described and also the methods used in investigating them,—all in an interesting manner. As might be expected, special attention is given to the researches of French scientists. On page 66 is found the statement that the value of the "solar constant" maybe taken *without fear of very considerable error* at 2.75, this result being obtained from Violle's best measurements. Many will disagree with this

C. A. CHANT.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

Information Regarding the Aurora

The *Monthly Weather Review* for July last contained a large amount of information regarding the great aurora of March 22-25 1920, and auroras in general, which has been reprinted in a pamphlet of 16 large pages. The numerous reports show that the periods of greatest brilliance and maximum magnetic activity were simultaneous throughout the world. This aurora ranks among the greatest five world-wide displays in the past eleven years, embracing the recent sunspot maximum. In many places it was the most brilliant one seen in this century.

During this aurora Störmer of Christiania, Norway, obtained a unique collection of photographs. He was at Bygdö while six associates were at places from 26 to 89 km. distant from each other, all connected by telephone. This allowed many simultaneous photographs of the same features of the display to be taken, and these will be used to determine the height and location in space of those parts of the display. Some years ago Störmer obtained a number of such photographs and from them he deduced the only trustworthy measurements of heights which we have. Already a few calculations have been made from the new plates and they show that the summits of the auroral rays in some cases were 500km. above the earth's surface. This is, I believe, the greatest height so far determined for an atmospheric phenomenon.

Rainbow Phenomena

In Humphreys' recent and valuable work, "Physics of the Air", is a somewhat elaborate treatment of the rainbow containing many facts not ordinarily known. I quote two paragraphs (p. 456):

> The records of close observations of rainbows soon show that not even the colours are always the same; neither is the band of any colour of constant angular width; nor the total breadth of the several colours at all uniform; similarly the purity and brightness of the different colours are subject to large variations. The greatest contrast, perhaps, is between the sharply-defined brilliant rainbow of the retreating thunderstorm and that illy-defined faintly tinged bow that sometimes appears in a mist—the "White bow" or "fog bow".

All the differences depend, as will be explained later, essentially upon the size of the drops, and therefore inequalities often exist between even the several portions, especially top and bottoms, of the same bow, or develop as the rain progresses. Additional complications occasionally result from the reflection of bows and from bows produced by reflected images of the sun, but though unusual and thus likely to excite wonder and comment such phenomena are easily explained.

Under date November 5, 1920, Mr. B. S. Wimbush, of Garden Plains, Alberta, sends some interesting notes on the "sun drawing water", and concludes:—

Once in the summer several years ago I saw something which I never saw before or since, two rainbows in one cloud, or two parts of rainbows, at different angles! I wondered how it occurred, and then noticed the beam that made it. It was reflected from the lake (Sullivan Lake); which, by the way, turned white to-day for the first time, after a flurry of snow.

Donation to the Society's Library.

Recently the Library of the Society received a handsome donation of some ninety-two volumes of the publications of the Paris Observatory. They consist of *Annals* (including *Observations* and *Memoirs*), and the *Bulletin* of the Permanent International Committee of the Carte du Ciel. The Society is indebted to M. Baillaud, the director of the Observatory, who recommended to the French Government that the volumes be sent, and to the Government at Ottawa for facilitating their free transmission by post.

Notes.

Recently a splendid sheaf of *Publication* of the Allegheny Observatory was received. They are largely devoted to stellar parallases, the results for 315 stars being given, but they include also a research into atmospheric refraction and a list of wave-lengths of Fraunhofer lines from 6,500 A to 9,000 A.

Numerous *Scientific Papers* of the Bureau of Standards at Washington have also been received. They are of high value and show the scientific productiveness of that great institution. Canada should soon provide a similar one. C.A.C.

Erratum.—On page 388, line 3, *inches* should be *feet*.

INDEX TO VOLUME XIV.

A.

Aberration of Light, A simple apparatus for illustrating the, *John Satterly*, 89.

Annual General Meeting of the Society, 70.

American Astronomical Society, The Twenty-fourth meeting of the, *Ralph E. DeLury*, 351.

Appointments of Canadian Scientists, 40.

Astronomical Journal, New Swedish, 387.

Astronomical Notes, *J. R. Collins*, 37, 83, 122, 265, 309, 347.

Astronomical Observatory for Upper Canada, *Otto Klotz*, 365.

Astronomy, Some Problems of Sidereal, 309.

Auroral Streamers, Focus of, *C. A. Chant*, 268.

Aurora, March 22nd, 1920, *A. F. Hunter*, 128, *J. P. Henderson*, 127, *J. E. Maybe*, 128; How High is the, 125; A fine, 127.

Astrophysical Observatory, Notes from the Dominion, *J. S. Plaskett*, 428.

B.

Barker, H. W. Pin-hole or Lensless Photography, 16.

Book Reviews, *C. A. Chant*, 35, 161, 218, 263, 434, *W. E. Harper*, 157.

Binaries, The Spectio copic Orbits and Dimensions of the Eclipsing Variables, U Ophiuchi, RS Vulpeculae and T W Draconis, *J. S. Plaskett*, 1. The Spectroscopic Orbits and Dimensions of the Eclipsing Variables, U coronae, TX Hercules, and Y Cygni, *J. S. Plaskett*, 409. The Orbit of the Spectroscopic Binary H. R. 6385, *W. E. Harper*, 328.

Brashear, Dr. John A., *Frank C. Jordan*, 200, Death of 171.

Barnard, Visit to Toronto, 126.

C.

Calcium Lines H and K in Early, type Stars, *R. K. Young*, 389.

Calcium Envelope Hypothesis, A Possible Extension of the, *W. Carl Rufus*, 139.

Canadian Scientists, Appointment of, 40.

Carrington, F. S., An Amateur's Observatory, 141.

Cepheid Variable RS. Orionis, *F. Henroteau*, 360.

Chant, C. A., Book Reviews, 35, 161, 218, 263, 434; The Sun Drawing Water, 311, 348, 388; Notes and Queries, 39, 84, 126, 171, 218, 268, 311, 348, 385, 435; Librarian's Report, 77; The Coming Disappearance of Saturn's Rings, 385. The Death of Dr. John A. Brashear, 171.

Collins, J. R., Astronomical Notes, 37, 83, 122, 265, 309, 347.

Coutlee, C. R., Helps to remember sizes and distances of the Planets, 387.

Curious Effect obtained by superposing two photographs of Star Fields, from which an accurate method of measuring small distances can be devised, *F. Henroteau*, 363.

Curtis, Heber D. ,Modern Theories of the Spiral Nebulae, 317.

Cornu, Death of Dr. Jules, 39.

Committees, Members of National, 219

Changes in Period of Variable Stars, 310.

Creed, of a Present Day Physicist, The Manifold, 347.

D.

DeLury, Ralph E., The Twenty-fourth meeting of the American Astronomical Society, 351.

Davis, Dr. H. S., Recollections of R. G. Haliburton, 84.

Dominion Astrophysical Observatory, Notes from, *J. S. Plaskett*, 428.

E.

Earthquake Records at Toronto and Victoria, 34, 79, 118, 168, 216, 261, 307, 346.
Earthquake, January 24th, 1920, 119
Errors in the Handbook, 40.
Eclipse of one Satellite of Jupiter by another, *A. R. Hassard*, 173.
Erastosthenes I, a Study for the amateur, 122.
Einstein's Relativity Theory, 123.
Example of Sunlight Engineering, 311.
Engineering, Sunlight, in relation to Housing and Town Planning, *H. L. Seymour*, 129.

F.

Festival of the Dead, *R. G. Haliburton*, 19, 59, 99, 144, 248, 292, 335, 369, 425.
Firm, Forty years' Growth of a well-known, 315.
French, C. A., Magnetic Results, 1919, 331.
Focus of Auroral Steamers, 268.

G.

Globe of the Planet Mars, *A. F. Miller*, *18*.
Gravitation, The Theory of, 83.
Gravitation, Newtonian, *Otto Klotz*, 285.

H.

Haliburton R. G., The Festival of the Dead, 19, 59, 99, 144, 248, 292, 335, 369, 425.
Recollections of, *Dr. H. S. Davis*, 84.
Halo, An Unusual, *C. A. Chant*, 176.
Halley's Comet, Query on, 39.
Harper, W. E., Book Reviews, 157, The Orbit of the Spectroscopic Binary H. R. 6385, 328.
Hassard, A. R., Eclipse of one Satellite of Jupiter by another, 173.
Henderson, J. P., Observation of Aurora, March 22nd, 1920, 127.
Henroteau, F., Curious Effect obtained by superposing two photographs of star fields, from which an accurate method of measuring small distances can be devised, 363, The Cepheid Variable R. S. Orionis, 360, The Emotion of the Solar System, 234. The possible Role of Radiation pressure in Stellar Physics, 93.
Herbert, W. H., Deviation of Magnetic Declination in Western Canada, 239,
Hunter, A. F., Observation of Aurora. March, 22nd, 1920, 127.

J.

Jordan, Frank C., Dr. John A. Brashear, 200.
Jupiter, Eclipse of one Satellite of, by another, *A. R. Hassard*, 173.

K.

Klotz, Dr. Otto., An Astronomical Observatory for Upper Canada, 365; Newtonian Gravitation, 285; Observatory Club, 386; Sun Dials, 205; Sun's altitude, 288; President of the Seismological Society of America, 220.

M.

Magnetic Declination, Deviation of, in Western Canada, *W. H. Herbert*, 239.
Magnetic Disturbances, 81, 169, 214, 345, 380.
Magnetic Observations, 120.
Magnetic Results, 1919, *C. A. French*, 331.
Mars, Globe of the Planet, *A. F. Miller*, 18.
Maybe, J. Edward, Observation of Aurora, March 22nd, 1920, 128.
Meetings of the Society, at Ottawa, 30; at Toronto, 29, 70, 112, 164, 211, 377; at Victoria, 31.
Meteor, Reported in Oklahoma, 218.
Meteor, A Bright, 88.
Meteorological Service, Notes from the, 32, 78, 116, 166, 213, 260, 306, 344, 379, 430.

Miller, A. F., Globe of the Planet Mars, 18; Some Results of Astronomical work during 1919, (Retiring President's Address), 41.
Members of National Committees, 219.
Manifold Creed of the Present-day Physicist, 347.

N.

National Committees, Members of 219.
New Stars, News about, 265.
Newtonian Gravitation, *Otto Klotz*, 285.
Notes and Queries, *C. A. Chant*, 39. 84, 126, 171, 218, 268, 311, 348, 385, 435.
Nova, Visible to the Naked Eye, 348.
New Swedish Astronomical Journal, 387.
Notes from the Dominion Astrophysical Observatory, *J. S. Plaskett*, 428.
Observations, 315.
Observation of Planetary Details, 125.
Observatory, An Amateur's, *F. S. Carrington*, 141.
Observatory, Notes from the Dominion Astrophysical, *J. S. Plaskett*, 248.
Observatory Club, *Otto Klotz*, 386.
Optical Parts of the 72-inch Telescope, *J. S. Plaskett*, 177.
Origin of Spectra, The, *H. H. Plaskett*, 221, 269.

P.

Period of Variable Stars, Changes in 310.
Photography, Pin-hole or Lensless, *H. W. Barker*, 16.
Plaskett, H. H., The Origin of Spectra, 221, 269.
Plaskett, J. S., The Optical Parts of the 72-inch Telescope, 177; The Spectroscopic Orbits and Dimensions of the Eclipsing Variables, U Ophiuchi, RS Vulpeculae, and T W Draconis, 1; The Spectroscopic Orbits and Dimension of the Eclipsing Variables, U Coronae TX Hercules and Y Cygni, 409.
Planetary Detail, Observation of, 125.
Pleiades, The Year of the, *R. G. Haliburton*, 19, 59, 99, 144, 248, 292, 335, 369.
Pressure, The Possible Role of Radiation in Stellar Physics, *F. Henroteau*, 93.
Problems of Sidereal Astronomy, 309.
Physicist, The Manifold Creed of the Present-Day, 347.

R.

Radiation Pressure in Stellar Physics, The Possible Role of, *F. Henroteau*, 93.
Relativity, The Solar Eclipse and, *John Satterly*, 174.
Relativity Theory, Einstein's ,123.
Rufus, W. Carl, A Possible Extension of the Calcium Envelope Hypothesis, 139.
Rainbow, The "Unapproachable", 311.

S.

Saturn's Rings, The Coming Disappearance of, *C. A. Chant*, 385.
Satterly, Dr. John, A Simple Apparatus for illustrating the Aberration of Light, 89; The Solar Eclipse and Relativity, 174.
Schools, Star Study in, 124.
Seymour, H. L., Sunlight Engineering in relation to Housing and Town Planning, 129.
Solar Eclipse and Relativity, *John Satterly*, 174.
Solar System, The motion of, *F. Henroteau*, *234*.
Society, The State of the, 87.
Spectra, The Origin of, *H. H. Plaskett*, 221.

Spectroscopic Orbits and Dimensions of the Eclipsing Variables U Ophiuchi R S Vulpeculae, and T W Draconis, *J. S. Plaskett*, 1.
Spectroscopic Binary, H. R. 6385, The Orbit of the, *W. E. Harper*, 328.
Spiral Nebulae, Modern Theories of the, *Heber D. Curtis*, 317.
Star Study in Schools, 124.
Stellar Physics, The Possible Role of Radiation Pressure in, *F. Henroteau*, 93.
Sun Dials, *Otto Klotz*, 205.
Sun Drawing Water, *C. A. Chant*, 311, 348, 388.
Sunlight Engineering in relation to Housing and Town Planning, *H. L. Seymour*, 129.
Sunlight Engineering, An Example of 311.
Sun's Altitude, *Otto Klotz*, 288.
Sidereal Astronomy, Some Problems of, 309.
Swedish Astronomical Journal, New, 387.
Spectroscopic Orbits and Dimensions of the Eclipsing Variables U Coronae, TX Hercules and Y Cygni, *J. S. Plaskett*, 409.

T.

Telescope, The Optical Parts of the 72-inch, *J. S. Plaskett*, 177.

U.

"Unapproachable" Rainbow, The, 311.

V.

Variables, The Spectroscopic Orbits and Dimensions of the Eclipsing, U Ophiuchi, RS Vulpeculae, and TW Draconis, *J. S. Plaskett*, 1.
Changes in Period of, 310.
The Spectroscopic Orbits and Dimensions of the Eclipsing, U Coronae, TX Hercules and Y Cygni, *J. S.* Plaskett, 409.

Y.

Year of the Pleiades, The, *R. G. Haliburton*, 19, 59, 99, 144, 248, 292, 335, 369, 425.
Young, R. K., The Calcium Lines H and K in Early Type Stars, 389.

CONTENTS OF VOLUME XIV

I. JANUARY-FEBRUARY Page

The Spectroscopic Orbits and Dimensions of the Eclipsing Variables U Ophiuchi, RS Vulpeculae and TW Draconis - *J. S. Plaskett* 1
Pin-hole or Lensless Photography - - - *H. W. Barker* 16
A Globe of the Planet Mars - - - - - *A. F. Miller* 18
The Festival of the Dead - - - - *R. G. Haliburton* 19
Meetings of the Society, at Toronto, 29; at Ottawa, 30; at Victoria, 31. Notes from the Meteorological Service, 32; Book Reviews, 35; Astronomical Notes, 37; Notes and Queries, 39.

II. MARCH

Some Results of Astronomical Work during 1919 (Retiring President's Address) - - - - - - - - *A. F. Miller* 41
The Festival of the Dead (Continued) - - *R. G. Haliburton* 59
Meetings of the Society (Annual Meeting) - - - - - 70
Notes from the Meteorological Service, 78; Astronomical Notes, 83; Notes and Queries, 84.

III. APRIL

A Simple Apparatus for Illustrating the Aberration of Light *John Satterly* 89
The Possible Role of Radiation Pressure in Stellar Physics *F. Henroteau* 93
The Festival of the Dead, (continued) - - - *R. G. Haliburton* 99
Meetings of the Society, at Toronto - - - - - - 112
Notes from the Meteorological Service, 116; Astronomical Notes, 122; Notes and Queries, 126.

IV. MAY

Sunlight Engineering in Relation to Housing and Town Planning *H. L. Seymour* 129
A Possible Extension of the Calcium Envelope Hypothesis - *W. Carl Rufus* 139
An Amateur's Observatory - - - - - - *F. S. Carrington* 141
The Festival of the Dead, (continued) - - - *R. G. Haliburton* 144
Book Reviews, 157; Meetings of the Society, at Toronto, 164; Notes from the Meteorological Service, 166; Notes and Queries, 171.

V. JUNE

The Optical Parts of the 72-inch Telescope - *J. S. Plaskett* 177
Dr. John A. Brashear - - - - - - *Frank C. Jordan* 200
Sun Dials - - - - - - - *Otto Klotz* 205
Meeting of the Society, at Toronto, 211; Notes from the Meteorological Service, 213; Notes and Queries, 218.

VI. JULY

Page

The Origin of Spectra. - - - - - - *H. H. Plaskett* 221
The Motion of the Solar System - - - - *F. Henroteau* 234
Deviation of Magnetic Declination in Western Canada - *W. H. Herbert* 239
Magnetic Results, 1918-1919 - - - - *G. Blanchard Dodge* 242
The Festival of the Dead (continued) - - - *R. G. Haliburton* 248
Notes from the Meteorological Service, 260; Book Reviews, 263; Astronomical Notes, 265; Notes and Queries, 268.

VII. AUGUST-SEPTEMBER

The Origin of Spectra (concluded) - - - - - *H. H. Plaskett* 269
Newtonian Gravitation - - - - - - *Otto Klotz* 285
Sun's Altitude - - - - - - - - *Otto Klotz* 288
The Festival of the Dead (continued) - - - - *R. G. Haliburton* 292
Notes from the Meteorological Service, 306; Astronomical Notes, 309; Notes and Queries, 311.

VIII. OCTOBER

Modern Theories of the Spiral Nebulae - - - *Heber D. Curtis* 317
The Orbit of the Spectroscopic Binary, H. R. 6385 - *W. E. Harper* 328
Magnetic Results, 1919 - - - - - - *C. A. French* 331
The Festival of the Dead (continued) - - - *R. G. Haliburton* 335
Notes from the Meteorological Service, 344; Astronomical Notes, 347; Notes and Queries, 348.

IX. NOVEMBER

The Twenty-fourth Meeting of the American Astronomical Society *Ralph E. DeLury* 351
The Cepheid Variable RS Orionis - - - - - *F. Henroteau* 360
On a Curious Effect Obtained by Superposing Two Photographs of Star Fields, from which an Accurate Method of Measuring Small Distances can be Devised - - - - - - *F. Henroteau* 363
An Astronomical Observatory for Upper Canada - *Otto Klotz* 365
The Festival of the Dead (continued) - - *R. G. Haliburton* 369
Meetings of the Society, at Toronto, 377; Notes from the Meteorological Service, 379; Book Reviews, 383; Notes and Queries, 385.

X. DECEMBER

The Calcium Lines H and K in Early Type Stars - *R. K. Young* 389
The Spectroscopic Orbits and Dimensions of the Eclipsing Variables U Coronae, TX Hercules and Y Cygni - *J. S. Plaskett* 409
The Festival of the Dead (continued) - - - *R. G. Haliburton* 425
Notes from the Dominion Astrophysical Observatory - *J. S. Plaskett* 428
Notes from the Meteorological Service, 430; Book Reviews, 434; Notes and Queries, 435; Index to volume XIV, 1920, 437.

The Royal Astronomical Society of Canada

OFFICERS FOR 1920 (Revised to April 1st, 1920).

Honorary President—Otto Klotz, LL.D., D.Sc., F.R.A.S.

President—J. R. Collins. *First Vice-President*—W. E. W. Jackson, M.A.

Second Vice-President—Wm. Bruce, J.P.

General Secretary—A. F. Hunter, M.A. *General Treasurer*—H. W. Barker.

Recorder—J. A. Pearce, B.A. *Librarian*—Professor C. A. Chant.

Curator—R. S. Duncan.

Council—Sir Joseph Pope, K.C.M.G.; Rev. Dr. Marsh, F.R.A.S., Sc.D.; Stuart Strathy; John Satterly, M.A., D.Sc.; Dr. W. M. Wunder; Samuel Beatty, Ph.D.; R. A. Gray, B.A.; A. R. Hassard, B.C.L.; Professor L. Gilchrist; Rev. Professor F. D. Meader; and past Presidents: John A. Paterson, K.C., M.A.; Sir Frederick Stupart, F.R.S.C.; Professor A. T. DeLury; Professor L. B. Stewart; Albert D. Watson, M.D.; J. S. Plaskett, B.A., D.Sc.; A. F. Miller; and the presiding officers of each centre: C. A. Bigger, D.L.S., Ottawa; Professor L. A. H. Warren, Ph.D., F.R.A.S., Winnipeg; R. K. Young, Ph.D., Victoria; Mgr. C. P. Chouquette, M.A., Lic. Scs., Montreal; R. R. Graham, B.A., Guelph.

OTTAWA CENTRE

President—C. A. Bigger, D.L.S. *Vice-President*—Dr. W. Bell Dawson.

Secretary-Treasurer—R. M. Motherwell, M.A.

Treasurer—D. B. Nugent, M.A.

Council—Thos. Fawcett, D.T.S.; Albert Hawkins, D.L.S.; R. E. DeLury, Ph.D.; and Past Presidents: Dr. Otto Klotz; R. M. Stewart, M.A.; Dr. J. S. Plaskett; F. A. McDiarmid, M.A.; J. J. McArthur, D.L.S.

VICTORIA CENTRE

Honorary President—J. S. Plaskett, D.Sc.

President—R. K. Young, Ph.D. *Vice-President*—J. E. Umbach.

Secretary—K. M. Chadwick. *Treasurer*—J. P. Hibben.

Council—Dr. Etta Denovan, Mrs. W. Christopher, G. S. McTavish, F. C. Green, G. G. Aitken, W. E. Harper, and Past Presidents: F. Napier Denison, A. W. McCurdy and W. S. Drewry.

WINNIPEG CENTRE

Honorary President—Frank Powell.

President—Professor L. A. H. Warren, Ph.D., F.R.A.S.

Vice-President—J. H. Kolb.

Secretary-Treasurer—Professor H. R. Kingston, M.A., Ph.D.

Council—Mrs. W. E. Howey, H. B. Allen, C. E. Bastin, B.A.; H. E. Riter, B.A.; Professor N. B. MacLean, M.A., F.R.A.S.C.

MONTREAL CENTRE

President—Mgr. C. P. Choquette, M.A., Lic. Scs.

Vice-President—H. E. S. Asbury.

Secretary-Treasurer—Rev. W. T. B. Crombie, M.A., B.D.

Council—Geo. Sample, James Weir, B.Sc.; Lt.-Col. W. E. Lyman, B.A.; Miss M. Ellicott, John Conway.

GUELPH CENTRE

Honorary President—James Davidson, B.A.

President—R. R. Graham, B.A., B.S.A.

1st Vice-President—Lt.-Colonel D. McCrae.

2nd Vice-President—J McNeice, B.A.

Secretary-Treasurer—H. Westoby. *Recorder*—J. W. Charlesworth, B.A.

Council—Mrs. J. J. Drew; Miss Mary Mills; F. A. Graesser; Professor W. H. Day, M.A.; J. M. Taylor, Sr.; Wm. Laidlaw; Col. A. H. MacDonald; H. J. B. Leadlay.

FOR SALE OR EXCHANGE

Harvard Annals

Vol. 11; Vol. 12; Vol. 13; Vols. 15-23 inc.; Vol. 41, parts 1, 3, 9; Vol. 42, parts 1, 2; Vol. 43; Vol. 48; Vol. 49; Vol. 51; Vol. 53; Vol. 56, parts 1, 2; Vol. 58; Vol. 60; Vol. 65; Vol. 68, part 1.

Apply to C. A. CHANT,
Librarian R.A.S.C.

FOR SALE

TWO

Rochon's Micrometer Telescopes

Diameter of Objectives, 1½in. clear aperture

Apply—

HEARN & HARRISON,
418 Notre-Dame St. West, Montreal